A LIMITED ANTIBALLISTIC MISSILE SYSTEM

THESIS

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THESIS APPROVAL

STUDENT: Captain Jay H. Payne CLASS: GSO 90-D

THESIS TITLE: A Limited Antiballistic Missile System

DEFENSE DATE: 27 NOV 90

COMMITTEE:	NAME/DEPARTMENT	SIGNATURE
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AFIT/GSO/ENS/90D-14

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Space Operations

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December, 1990

Acknowledgments

This thesis culminates months of brainstorming, research, computer time, and composition. While my name appears on the cover, it would not have been possible without the help and support of others.

I would like to thank Major Bruce Morlan, my advisor, for his patience, encouragement, direction, and mostly for his dedication to his students. The concept for the thesis was his, I hope I did it justice.

As a management major, I had little background in engineering. Without the help of classmates Steve Wilson and Bill Gaught I would never have made it through the classes that gave me the skills to accomplish this work. Their late night tutoring sessions were invaluable to me.

The last few months were made easier by my fiancee, Cindy. Her help and encouragement kept me going when I was frustrated, stuck, or dissappointed, and allowed me to finish on time. It will be a pleasure spending the rest of my life repaying her.

Most importantly, this work is dedicated to my father. He came with me to AFIT, and I leave with memories of him.

Jay H. Payne

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Abstract

This investigation examines the possibilities of deploying a limited ABM system to counter launches from Third World regions. It is a systems analysis of the entire concept, with the objective of determining if the existing missile warning network could detect launches from Third World regions, and if an ABM component could be integrated into the network. A computer model was used to determine if launches would be detected, and examine the warning time provided. Based on sample data, the warning network appears capable of detecting Third World launches. Warning times provided by the network appear to provide adequate time to communicate the event up through the National Command Authorities, and launch an interceptor. The ABM structure could be integrated into the existing network, using the unified command currently operating it. The entire US could be defended using 12 batteries of interceptors with a range of 350 miles. It appears the most questionable aspect of the system is the interceptor missile. There are several interceptors under development, but none have been fully operationally tested. The ERIS interceptor under development by the Army may have the capabilities to be used in the system. Further research could prove the system to be a valuable asset.

A LIMITED ANTIBALLISTIC MISSILE SYSTEM

I. *Introduction and Background*

1.1 Background

Recent years have brought many changes in the world's political climate. Defense planners must constantly assess these changes and the relationships the United States has with other countries, and attempt to formulate short and long term strategies to obtain national objectives. One major change has been the introduction of nuclear weapons into the arsenals of Third World countries. Many Third World countries have acquired or are attempting to acquire space launch capabilities. Since a vehicle that can boost an object into orbit can be adapted to boost a warhead into a ballistic flight, the combination of nuclear weapons and ballistic boosters provides a new threat to the US.

One possible defense against an attack from an Intercontinental Ballistic Missile (ICBM) is the use of an Anti-Ballistic Missile (ABM) system. The United States no longer has an ABM capability, and in 1972 signed a treaty prohibiting further development of one (21:1-5). When the current treaty was signed, the threat of a ballistic missile attack came from the Soviet Union. Several ABM systems were designed but never fully implemented.

The US currently operates a world wide missile warning network of radar and satellite coverage. Since warning is an integral part of any ABM system, an examination of the current system, including the command, control, and communications (C^3) network, will determine its utility in an ABM role.

While a small scale ABM system may be overwhelmed by a mass attack, it may be a useful defense against a single or small launch. An examination of the threat, US current capabilities, and possible developments could help policy makers better define strategy.

1.2 Specific Problem

It is the purpose of this investigation to determine if the existing missile warning network could detect a missile launched toward the US from various Third World countries, and examine what additional developments are needed for the US to deploy an ABM system that would be used in defense of those launches.

The investigation focuses on an ABM system designed to defend the continental US against a very small launch, assuming Third World countries have neither a Sea Launched Ballistic Missile (SLBM) capability, nor the capability to launch a massive ICBM attack. The objective of the system would be defense against this small attack, not an impenetrable shield capable of defending against a US - USSR exchange. Based on these assumptions, this investigation examines the possibility of employing the missile warning radars already in use, modifying the command, control, and communications (C^3) network as little as possible, and employing ground based interceptors. By focusing on the existing network, this approach would attempt to minimize costs as much as possible, and focus on technology that is currently in use or could be available in a minimum of time.

1.3 Research Justification

The justification for this investigation lies in the changes in the world's political climate, and current budgetary constraints of the United States. The Strategic Defense Initiative is years from implementation, is many orders of magnitude more costly, and is designed to counter a much larger threat. Recent actions by Iraq have demonstrated the instability in the Middle Eastern region, showing the threat to be real (11:49-50). The offensive capabilities of the United States are not necessarily an effective deterrent to a Third World enemy. A low cost, limited capability system may prevent a tragedy.

1.4 Research Questions

- Would launches from various Third World regions be detected by the current missile warning radar network, and how much warning time would they provide if missiles are detected?
- What are the characteristics of an ICBM flight, and in what portion of this flight could the missile be intercepted?
- What are the methods available for interception?
- Is the warning time provided by the radar network sufficient to launch an interceptor?
- How would the existing missile warning network have to be modified to incorporate an ABM system into the network?

1.5 Scope

The intent of this investigation is to look at the feasibility of the entire system, not examine the technical aspects of ICBM interception. In order to maintain an unclassified study, a specific analysis of each current sensor's capabilities will not be provided. The framework for the system will be established, and the classified data could be incorporated later if desired.

Since the capabilities of Third World nations are somewhat ambiguous, the study will assume missile capabilities will be of the simplest design, that is single warhead, minimum energy trajectory, land-based launches.

The methods proposed for interception will be based on a literature review, not on research data. The intent of this investigation is to examine the possibilities of deploying a system, including detection, tracking, decision making architecture, and interception. It is not the intent of this investigation to design an ABM, or provide an in depth technical analysis of the hardware components of a system.

1.6 Organization

Following this introductory chapter, Chapter II of the thesis will continue with a review of literature that is pertinent to the investigation. Chapter III will outline the methodology used to answer the research questions outlined above. The methods described in Chapter III were used to obtain the results presented in Chapters IV and V. Chapter IV presents the results of a computer model used to solve some of the research questions, and Chapter V presents the possible structure and control of an ABM system. Conclusions and recommendations of the investigation have been placed in Chapter VI.

II. *Review of Pertinent Literature*

2.1 Introduction

Development of an ABM system is motivated by a perceived threat, and constrained by politics and technology. Its ability to be employed is further driven by the attack warning provided, and the command and control infrastructure that support it. To lend insight this chapter will review related literature, beginning with the philosophy behind ballistic missile defense, and the objectives of an ABM system.

ABM philosophy will be followed by an explanation of the basic phases a missile goes through in its flight. Included in this section are details about interception and destruction of missiles in the different phases.

The United States has developed several ABM systems in the past, and a review of these systems points out their philosophy, intent, and technology. A brief look at current developments will show the advances over the past systems.

A brief review of current developments in Third World ballistic missile technology establishes the extent of the current threat.

Since the system in this investigation would be incorporated into the existing missile warning network, a review of that network is essential. Unclassified information available will be used to describe the network.

2.2 ABM Philosophy

The philosophy behind an ABM system may not be readily apparent. How a country perceives a need for a system, the objectives of the system, success of a system is measured, and how a system is integrated into a defense strategy must be considered.

Ideally, any country that perceives a threat of missile attack would like to have an ABM system that would intercept and destroy all incoming missiles. While such an ABM system may be desirabl many factors influence the decision of whether or not to deploy a system. The cost of the system, its effectiveness against the threat, reactions by the enemy to the system, and trade-offs with other alternatives must all be evaluated to help with the decision.

The objective for an ABM system could be stated as the ability to destroy incoming missiles. This oversimplified objective doesn't reflect any measure of partial or complete success. While a system may be considered successful if it destroys a certain percentage of incoming missiles, the system is inadequate if the percentage of missiles it allows through causes unacceptable damage. The objectives must be clearly defined, stating whether an entire country is to be defended, or a point defense, such as the nation's capital.

Since this investigation focuses on a system to be used against a Third World threat, the primary objective of the system will be to intercept incoming missiles, not act as a deterrent.

The measure of success of a system may not even be in terms of missiles destroyed, but in forced reactions of the enemy to the deployed system. When defining the missions of an ABM system, Charles Herzfeld did not use quantitative terms, but rather subjective concepts: "First, the defense should exact a price from the offense of the other side, and second, it should complicate the attacker's job, and deny him a free ride" (10:16). Deployment of an ABM system forces an enemy to evaluate their offensive strategy, and decide if the system could be overwhelmed by increasing the size of the attack. The system also forces the enemy to determine how they can best respond to the system, given the time and financial constraints.

Another aspect of an ABM system is the scope of the system's objectives. An ABM system may be designed to protect a certain geographical region, population centers, or offensive weapons. If an ABM system protects a country's ability to retaliate to a first strike, it may be part of an effective deterrent even though it allows a large population loss. If the threat of retaliation is not an effective deterrent to an enemy, then the objective of the system will be to reduce damage from an attack. Destruction of all incoming missiles may be the objective when the threat is not from a massive attack, but from a small, errant, or accidental launch.

The confidence a country has in an ABM system may affect its entire defensive posture. If the general public or congress perceives the system as very effective, offensive capabilities may be reduced. Reliance on the ABM system could be disastrous if changes in an enemy's offensive capabilities make the ABM system inadequate, and offensive capabilities haven't been improved. The Air Force feared such reliance on a proposed US system in 1957, and attempted to persuade the Joint Chiefs of Staff that good offense was more desirable than a good defense (22:35).

Clearly an ABM system is not an independent system, but a segment of an overall defense strategy. The level of interception capability, and the ability to make an enemy react to the system are traditionally among the chief measures of effectiveness of a ABM system. Secretary of Defense Robert McNamara reflected on the use of an ABM system in his 1965 annual posture statement. McNamara felt an effective defense must include a combination of offensive and defensive forces to be balanced and effective (22:53). When a system is being measured against a Third World threat, interception capability may become the primary objective. Since the US does not expect Third World countries to match our arsenal, or overwhelm an ABM system with a massive attack, the primary concern becomes defending against an attack.

2.3 Ballistic Missile Flight Phases

A ballistic missile goes through several phases during its journey from launch to impact. The Government Advisory Panel on New Ballistic Missile Defense Technologies lists four phases of ballistic missile flight (20:141- 146). Carter and Schwartz use the same phases when they discuss the flights in *Ballistic Missile Defense.* A typical ballistic missile flight showing the phases is depicted in 2.1.

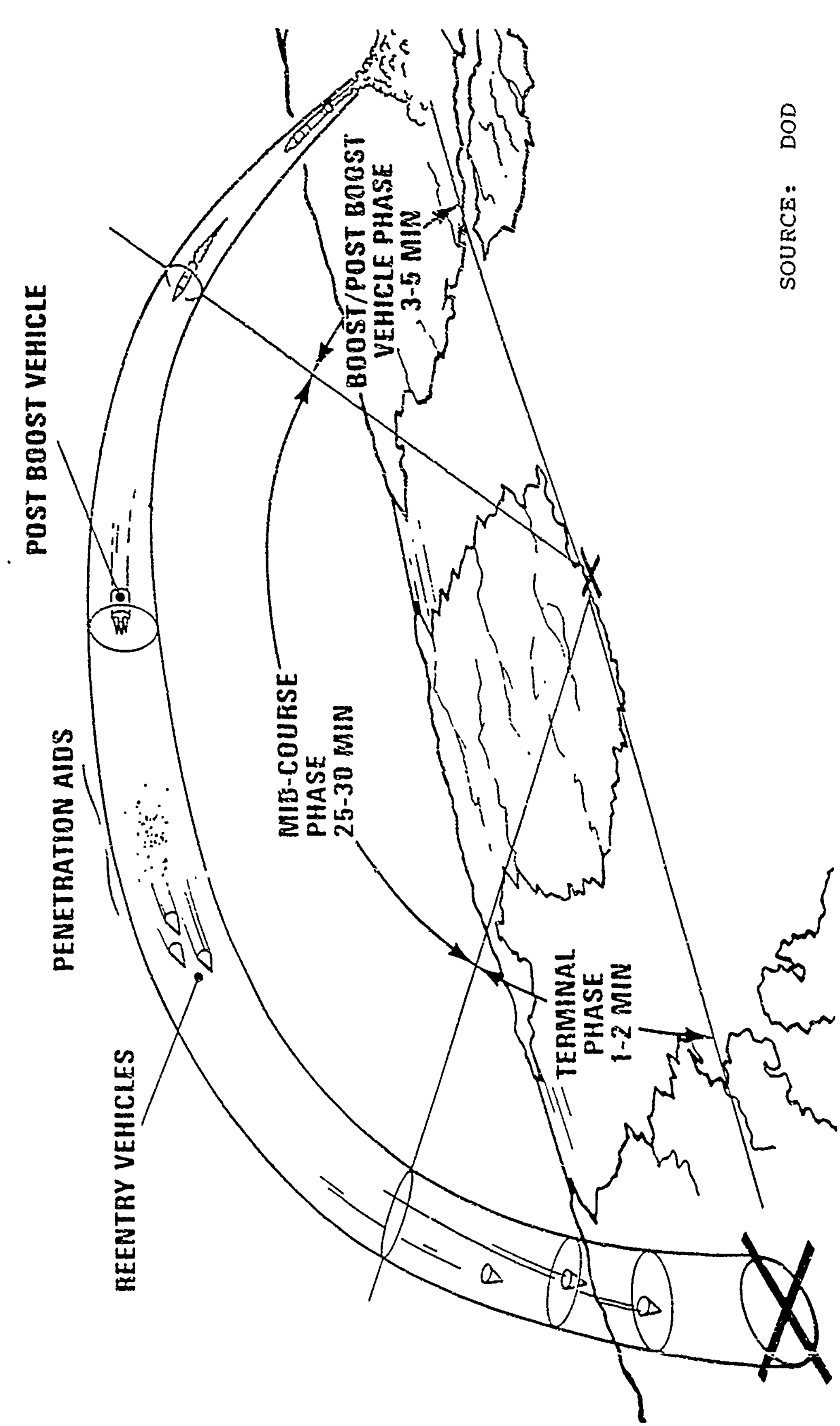


Figure 2.1. Ballistic Missile Flight Phases

The first phase of flight is called the Boost Phase. This is the period when the ICBM's booster is burning. Modern ICBMs generally remain in this phase approximately 3 to 5 minutes (20:141). During boost phase missiles can reach altitudes of 200 kilometers, and velocities of 7 kilometers per second (5:52).

When the missile's booster burns out and separates, the flight enters the Post-Boost Phase. In this phase, the post-boost vehicle will deploy the warheads, and if they are used, chaff and dummy warheads (decoys). This phase is from 1 to 6 minutes long, depending on the number of warheads to be deployed (20:144). The post-boost vehicle may maneuver to obtain very precise trajectories for the warheads (5:52).

The majority of the flight time is spent in the Midcourse Phase. The deployed warheads travel up to 20 minutes before they enter the Earth's atmosphere (20:144). The midcourse phase is the unpowered ballistic flight after the boost and post boost phases, before the objects reenter the atmosphere.

The last phase of flight is called the Terminal Phase. This short phase is the portion of flight between reentry into the atmosphere and impact or detonation. During this phase the dummy warheads usually burn up as they reenter the atmosphere (20:145). Reentry usually lasts from 30 to 100 seconds, depending on the characteristics of the warhead, the range, and the reentry angle(5:53).

The different phases of flight each present unique opportunities and problems for an ABM system. During the boost phase, the missile produces a large amount of heat, which is easily detected as infrared light by space based sensor (5:52). Since the boost phase is so short, it would be difficult to detect a launch, determine it is a threat, and launch an interceptor in this phase (20:141-142). The post boost phase is also short and results in similar problems. Since the booster is no longer burning, space based sensors may not detect enough infrared energy to track the missile.

The midcourse phase provides the longest period for radar systems to acquire and track the deployed warheads. Tracking the warheads allows prediction of trajectory and impact points (5:60). The tracking also allows time for extensive computer processing required for discrimination, which is the process of determining whether the object is a decoy or a reentry vehicle (5:61). Finally, like the boost phase, the terminal phase provides a very short time for interception of reentry vehicles (20:144)

2.4 Past US Systems

The United States officially began an ABM program on January 16, 1958 (22:26). It is important to note the reasons for the system, and its objectives. At the time the system was conceived, the threat was from Russia. While the system examined in this investigation considers a different threat and does not necessarily have the same objectives, the capabilities and concepts of past systems are still valuable. In 1958, Secretary of Defense Neil McElroy gave the Army responsibility to develop an ABM program, called Nike-Zeus (22:26).

2.4.1 NIKE-ZEUS. Nike-Zeus had grown out of the Nike missile program, which began in 1944. The Nike-Zeus was developed as an Antiballistic missile in 1953, and full scale development began in 1957 (22:27-28). While the Army was developing the missile, the Air Force was attempting to discredit the program. The Air Force staff believed the cost of adding one more warhead to the Russian arsenal would always be less than the cost of adding an ABM to stop it. In November of 1957, senior staff from the Air Force briefed the Joint Chiefs of Staff on why the system should not be deployed:

> The basis of deterrence to general war must be the nation's strategic offensive capabilities. Deployment of the Army's missile would contribute to the popularization of a Maginot Line myth; the Zeus system was technically deficient, since it could be fooled and overloaded by decoys and other objects; the earliest anticipated deployment date was 1961 - too late to neutralize the anticipated "missile gap"; and the Soviet Union

would undoubtedly offset any protection obtained by the United States from Zeus deployment by increasing its offensive missile threat (22:35).

The Air Force's efforts were unsuccessful, and development continued. There were enough doubts about the system to restrict funding; in 1959, the Army requested 1.3 billion dollars for the program, and Congress cut it to 437 million (22:60).

The Nike-Zeus missile was a rather slow interceptor designed to intercept missiles in the later midcourse and terminal phases of flight, consequently, it had a very limited range (10:4). Another problem associated with the system was the radar used to track targets and guide the interceptors. The radars were mechanically steered, meaning the dishes had to be physically turned in the direction of the object they were tracking. This made them slow and inefficient, and, "made it possible for the system to be overwhelmed by relatively simple tactics" (10:5).

The Nike-Zeus program was discontinued in 1964, after the Army conducted a series of tests, successfully intercepting 10 of 14 missiles (3:5). The project was not abandoned, but evolved into the Nike-X program.

2.4.2 NIKE-X. The new program incorporated new radars and replaced the interceptor missile (22:79). The new system used electronically steered radar (phased array) to eliminate the problems the old system had with being overwhelmed. The Sprint missile added to the system was a much higher speed interceptor, allowing it to intercept the missiles much later in flight (10:5-6). The missile had intercept ranges from 20 to 100 kilometers (3:5). The Sprint missile used a small nuclear warhead to destroy incoming missiles.

2.4.3 SENTINEL. On September 18, 1967, Secretary of Defense McNamara announced plans for the deployment of an ABM system called Sentinel. McNamara cited four grounds for the deployment: It would be relatively inexpensive, would provide limited protection from Chinese launches, defend US missile silos, and add protection of population against accidental launch (22:120-122).

The composition of this system changed as it developed. It started with the basic Nike-X system, and later added new radars and a second interceptor missile. The new missile was called Spartan, and was designed to have longer range, up to 650 kilometers, and intercept missiles outside the atmosphere (10:5-7). The new radar was a large, long range radar called Perimeter Acquisition Radar (PAR). PAR was designed to provide early warning and track many objects simultaneously at ranges of several thousand kilometers (6:5-6). The entire system was to have 5 PARs, 15 Spartan batteries, and several hundred Sprint missiles, at a cost estimated at $5.5 billion (6:11). Development and partial deployment of the Sentinel program continued until 1969.

2.4.4 SAFEGUARD. Melvin Laird, Richard Nixon's secretary of defense, froze the Sentinel system on February 6, 1969, for an evaluation of the system (22:144). After a month long evaluation, President Nixon announced the Sentinel program was inadequate, and modifications would be made. The new program would be called Safeguard (22:145). The intent of the new program was protection against a Soviet attack, primarily defending the ICBM missile fields. The new system would essentially be the same components as the Sentinel program, with two additional PAR radars, which would be oriented slightly differently (6:11).

The new system came under criticism quickly. Senator Edward Kennedy called for an outside appraisal of the system, and many scientists and engineers responded. The results of various studies were compiled and published by Abram Chayes and Jerome Weisner in 1969. In their book, *ABM: an Evaluation of the Decision to Deploy an Antiballistic Missile System*, they concluded the Safeguard system was inadequate and should not be deployed because it could not be tested, past experience with similarly sophisticated systems suggested a low probability of success in meeting specifications, and an overwhelming probability that components in the system would fail and result in a loss of coverage (6:12-17).

In May of 1972, President Nixon signed the ABM treaty. At this time the Safeguard system had deployed one PAR radar with Spartan and Sprint missiles, near Grand Forks, North Dakota. While the treaty allowed the US to keep the deployed site, and allowed one additional site to defend the Capital, the US judged that one or two sites did not justify the cost of operations, and deactivated the system (6:52).

2.4.5 Other Programs. Each of the services had several ventures into ABM systems. The Air Force had Wizard and BAMBI, the Navy had Typhoon, the Army had Saint and FABMDS (5:22). None of these system were ever deployed, and will not be discussed here.

2.5 Current ABM Developments

While the US discontinued its deployed ABM system with the closing of the Safeguard system, new efforts in ballistic missile defense started with President Ronald Reagan's "Star Wars" speech in 1983. The Strategic Defense Initiative Organization (SDIO) was tasked with the "research to define the technologies that could defend against ballistic missile attack" (19:27). While a complete review of the SDI program is not necessary here, there are some applicable areas that will be presented in brief detail. Under the direction of the SDIO, several new missiles designed to intercept incoming ICBMs are being developed. Of particular interest are the *FLAGE, ERINT, ERIS.* and *HEDI* missiles. The US is also jointly developing an ABM with Israel, called *ARROW* (18:6-10).

2.5.1 FLAGE. The Army Strategic Defense Command developed the Flexible Lightweight Agile Guided Experiment (FLAGE) program. The FLAGE program ended in 1987, after a successful intercept of a Lance missile was accomplished in May of 1987. Flage was designed to intercept missiles at a range of 4 kilometers, with a velocity of 3,000 feet per second. Flage uses a radar for homing in on the target (19:148-150).

2.5.2 ERINT. The Extended Range Intercept Technology (ERINT) program is a follow on to the FLAGE program. Several improvements have been made to the missile. The Intercept range was increased to 15 kilometers, and the missile can receive an update from ground based radar once during the flight. Velocity, radar power, and the maneuvering capability increased. The ERINT missile also has a "lethality enhancer", which is an explosive charge with tungsten pellets. The program calls for six test flights, the first to be in 1991 (19:148-150).

2.5.3 ERIS. The Exoatmospheric Reentry Vehicle Interception System (ERIS) is an interceptor designed to destroy missiles in the mid-course phase of flight. ERIS will use an Aries booster vehicle, then a homing vehicle will separate and track the incoming missile. While the interceptor is still in the conceptual stage, several tests have been performed on components, and on the operational concepts (19:131-132).

2.5.4 HEDI. The High Endoatmospheric Defense Interceptor (HEDI) is an interceptor designed to intercept incoming missiles in the late mid-course or early terminal phase of flight. The vehicle uses a Sprint type booster, with a homing vehicle that separates and activates an infrared seeker approximately four seconds before impact. The range of intercept is out to approximately 100 kilometers (19:132-134). The first test of the HEDI system was conducted on January 26, 1990, at White Sands Missile Range. Although many objectives of the test were successfully completed, the warhead separated and detonated several seconds earlier than planned. Several more tests are scheduled for the next two years (17:33).

There are two types of interception guidance methods being developed for the HEDI. The first system operates with radar guidance from ground based systems. The second is designed to use updates from an IR sensor, which is either ground or space based. The IR guidance updates are said to increase the range and accuracy of the interceptor (19:134).

2.5.5 Arrow. Israel is participating in the SDI program by developing an ABM missile called Arrow. The US is funding 80 percent of the program, with the first tests scheduled for 1991 (13:25).

2.5.6 Summary of ABM Characteristics. The previous sections provided descriptions of the various interceptors, both past and present. Examining the interceptors and the mission they were designed for helps establish some important interceptor characteristics:

- The minimum interception range of the missile, which establishes how close the incoming warhead can get, and how long launch of the missile can be delayed.
- The maximum interception range of the missile, which helps determine the maximum amount of area the missile can defend.
- The kill mechanism of the missile, which determines the effectiveness of the missile, and can limit its use.
- The guidance system for the missile, which determines the accuracy of the interceptor.

The current interceptors have been summarized in table 2.1.

	ERIS	ERINT	HEDI (1)	HEDI (2)
Range of Interception	Exoatmospheric Mid Course Interception	Endoatmospheric 10 - 15 km Terminal Phase Interception	Endoatmospheric Late Mid Course or Terminal Phase Interception	Endo - Exo Late Mid Course Early Terminal Interception
Warhead Guidance	Electro-optical Seeker Warhead	Radar Seeker Warhead	Electro-optical Seeker Warhead	Electro-optical Seeker Warhead
Guidance Updates	Possible IR Data from Ground or Space	Radar Guidance Update from Ground Based Radar	Ground Base Radar	Long Wave IR Data from Ground or Space

Table 2.1. Interceptor Characteristics

2.6 The Threat

The need for an ABM system against a small attack is predicated on the belief that Third World nations possess or have the potential of possessing the capability of a ballistic missile attack. Several countries now offer commercial sources for the acquisition of rocket vehicles designed to boost satellites into orbit, which obviously have the capability to boost a weapon into ballistic flight. While the technology for the development and production of a ballistic boost vehicle may be a simple matter, the production of nuclear weapons is not as commonplace. There is little doubt several countries are attempting to acquire both the technology and the resources to build nuclear weapons and there is strong evidence that several countries possess or are developing nuclear weapons.

2.6.1 The Middle East. Iraq's recent military actions testify to the instability of the Arab world, and to the willingness of Iraq to use its powerful military forces. Iraq already has a tactical missile capability, and is devoting many resources to the development of a nuclear weapon (11:49-50).

Pakistan may or may not already have the capacity to manufacture nuclear weapons. In March of 1987, *Newsweek* cited several sources claiming Pakistan already had joined the ranks of nations with nuclear power (15:45). The *Bulletin of Atomic Scientists* reported in June of 1987 that Pakistan has the equipment and the materials needed to produce weapons (23:30-32).

India has an impressive military arsenal, including nuclear powered submarines, an aircraft carrier, and a long range missile capability (9:27-28). With extensive nuclear power producing capabilities, it is likely that India already has or could produce nuclear weapons.

According to the May 1987 issue of *Technology Review*, Israel has a nuclear weapon capability, while Libya and Egypt have nuclear programs that will allow them to produce them (2:33). The *Air Force Times* reported that 27 nations have ballistic missile capability, including Syria and Saudi Arabia (13:25).

2.6.2 Latin America. Although most Latin American countries have signed an agreement regarding nonproliferation of nuclear weapons, several countries appear to be moving toward development and production of them.

The Latin American Nuclear Free Zone Treaty was signed in Mexico in 1967. The treaty forbids the development of and acquisition of nuclear weapons. Under a provision of the treaty, a nation may bind itself immediately to the treaty, or wait until all nations affected by the treaty have ratified it. Using this provision, Chile, Brazil, and Argentina do not consider themselves bound by the treaty because all nations in the treaty have not ratified it (16:52-56). The *Bulletin of Atomic Scientists* reported in November of 1989 that Brazil and Argentina have nuclear weapons making capabilities (23:5).

2.7 Missile Warning Network

The Air Force is responsible for providing warning of a ballistic missile attack against North America, and has assigned this responsibility to the North American

Air Defense Command (NORAD). NORAD is headquartered in Colorado Springs, Colorado, and performs its mission in conjunction with a unified command, United States Space Command. The Commander in Chief (CINC) of NORAD is also the CINC of US Space Command. This investigation will not distinguish between the two commands.

NORAD uses a missile warning network composed of radars and infrared (IR) sensors. The sensors are located worldwide, and report their data over high speed lines to the Missile Warning Center, which is located inside the Cheyenne Mountain Complex, in Colorado Springs.

The radar sensors used in the missile warning network are broken down into systems: Ballistic Missile Early Warning System, or BMEWS; the SLBM system, or PAVE PAWS; two intelligence gathering radars, Shemya and Pirinclik; and another sensor, PARCS. The sensors' capabilities are summarized at the end of this section in table 2.2, and the reporting chain is shown graphically in figure 2.6. All of the radar sensors are operated by squadrons of Air Force Space Command's First Space Wing. Air Force Space Command is the Air Force component of US Space Command. First Space Wing is responsible for the maintenance and manning of the sensors, but operational control rests with NORAD.

2.7.1 Ballistic Missile Early Warning System (BMEWS). BMEWS was conceived in late 1957 after the launch of Sputnik. The system was to be comprised of three radar sensors, to be located at Thule, Greenland; Clear, Alaska; and Fylingdales Moor, United Kingdom. Together the radars were to form a fan of coverage over the polar cap, and missiles launched at North America, or the European defended areas would have to fly through the fan. The primary mission of BMEWS is to detect and provide warning of an ICBM, MRBM, OR SLBM launch against the defended land areas. The secondary mission is to provide launch and impact data on the missiles, which is used for attack assessment (7:5). The BMEWS system is the primary means of ground based detection of an ICBM attack against the US. BMEWS radar coverage is depicted in figure 2.2.

SOURCE (7:69)

Figure 2.2. BMEWS Radar Coverage

2.7.1.1 Thule. The sensor at Thule AB, Greenland is a phased array radar, with two radar faces, each covering 120 degrees in azimuth,and 3 to 85 degrees elevation. The range is approximately 3000 miles (7:5).

Warning coverage is provided by a single surveillance fence, or radar energy beam, at 3.5 degrees elevation. Objects penetrating the fence are compared to a computerized catalog of known space objects. If the object is known, tracking is stopped. If the object is not recognized, the system continues to track it, while it performs a series of discrimination tests. If the system determines the object will impact in the defended area, a tactical warning message is immediately generated and released. The system continues to track the object and gather refined data, which is sent out as an attack assessment message. The system is capable of tracking multiple objects while still maintaining the surveillance fence.

2.7.1.2 Clear. The sensor at Clear AFB uses three detection radars and a tracking radar to perform its mission. The detection radars are huge reflector antennas, which project two fans of energy 3000 miles out into space at 3.5 and 7 degrees elevation. Each detection radar provides 40 degrees of azimuth coverage. As objects pass through the lower fan, the radar returns are fed to a computer, which performs a series of seven discrimination tests to determine if it is possible for the object to impact. If all seven of the discrimination tests are met, the object becomes a candidate for vector formation. When the object passes from the lower fan to the upper fan of a sector, the computer can then form a vector, and determine if the object will impact in the defended area , namely the US and Southern Canada. If the object will impact, a launch and impact message, or tactical warning message is generated and automatically released to the NORAD Cheyenne Mountain Complex (7:1-6). The tracking radar is designed to gather refined data on those objects identified as threats by the detection radars.

2.7.1.3 Fylingdales. BMEWS Site Three is located in England, at Fylingdales Moor. The site is comprised of three tracking radars. The normal mode of operation for the site is to use two of the trackers in a scan mode, performing a missile warning mission, and the third tracker accomplishing the space surveillance mission. Any combination of the trackers can be used, with the normal azimuth coverage for missile warning being 135 degrees (7:5).

The current system of trackers is being replaced by a phased array radar. The new system is to have three faces, provide 360 degrees of warning coverage, and is scheduled for completion in 1992 (5:68).

2.7.2 PAVE PAWS. The system designed to provide warning against an SLBM attack against the United States is called PAVE PAWS. The system is composed of four independent radar sites, at Cape Cod AFB, Beale AFB, Robins AFB, and Eldorado AFB.

Each of the sensors is a two faced phased array radar, providing 240 degrees of azimuth coverage out to a range of 3000 miles. The radars provide a surveillance fence at three degrees elevation, and can track objects up to 85 degrees elevation. The phased array radars can keep many objects in track simultaneously.

Objects passing through the surveillance fence are first compared to a computer library of orbiting objects to see if they match a known satellite. Those objects that are not known are tracked while the computer runs a series of discrimination tests to determine if they will impact, and if they will impact if they will impact in the defended area. If the computer determines the objects will impact in the defended area, a warning message is immediately generated and sent over high speed data lines to Cheyenne Mountain and to the National Military Command Center in the Pentagon (4). PAVE PAWS coverage is depicted in figure 2.3.

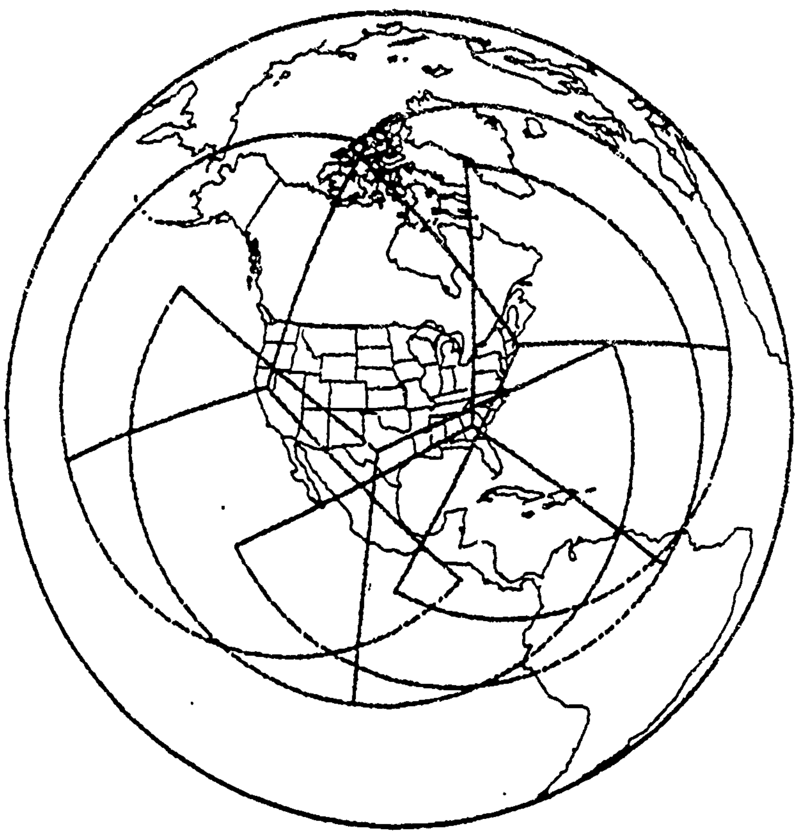


Figure 2.3. PAVE PAWS Radar Coverage

2.7.3 Intelligence sensors. Two of the sensors in the missile warning network have a primary mission of intelligence gathering. The sensors are located at Shemya AFB, Alaska, and Pirinclik AFB, Turkey. When they are not in the intelligence gathering mode, they perform the missile warning mission.

2.7.3.1 Shemya. Shemya is a single face, phased array radar, located on an island in the Aleutian chain. Its primary mission is to gather radar intelligence data on launches by the Soviet Union into the Kamchatka Peninsula and the Pacific Broad Ocean Area (BOA). Through various radar fences, Shemya can cover up to 240 degrees in azimuth, at an elevation of 2 to 86 degrees (5:71). Shemya's coverage is depicted in figure 2.4.

SOURCE (7:73)

Figure 2.4. Shemya Radar Coverage

2.7.3.2 Pirinclik. Pirinclik has a tracking radar and detection radar similar to those at Clear. Pirinclik's mission is to provide intelligence data on space and missile events. With the tracking radar, Pirinclik can cover 360 degrees in azimuth, but the tracking radar is normally not scanning for launches, but tracking space objects as tasked by the Space Surveillance Center (5:71).

2.7.4 PARCS. The last radar sensor is located at Cavalier AFB, North Dakota. PARCS is the remnant of the Safeguard system described above. A single faced, phased array radar, its mission is tactical warning and attack characterization. A capability that was built into the processing as part of the ABM system, attack characterization breaks the predicted impact points down into categories such as urban/industrial, command and control centers, missile fields, etc. The radar covers 140 degrees of azimuth (5:65). PARCS coverage is depicted in figure 2.5.

SOURCE (7:72)

Figure 2.5. PARCS Radar Coverage

Sensor	Location	Range	Azimuth Coverage	Elevation Coverage
BMEWS				
Thule	N76 E291	2900	297 to 177	3 to 85
Clear	N64 E210	2800		2 to 85
Fylingdales	N54 E359	2800	0 to 360	2 to 90
Pave Paws				
Cape Cod	N41 E289	3000	347 to 227	3 to 85
Beale	N39 E238	3000	126 to 85	3 to 85
Robins	N32 E276	3000	10 to 250	3 to 85
Eldorado	N31 E259	3000	70 to 310	3 to 85
Intel				
Pirinclik	N37 E39	*	0 - 360	2 to 86
Shemya	N52 E174	*	259 - 19	1 to 85
Other				
PARCS	N48 E262	*	313 - 63	1.9 to 85

* Classified information

Source: Space Operations Orientation Course

Table 2.2. Radar Sensor Specifications

2.7.5 Infrared Sensors. Another important part of the missile warning network is the Satellite Early Warning System (SEWS). While the locations of the units, and much of the information about the system is classified as SECRET, some data about the system is available at the unclassified level. For the purposes of this investigation, we will need to deal only with the unclassified portions.

The system is designed to detect the infrared heat given off by a missile in the boost phase of flight. Once the system detects the launch, its characteristics are compared to a library of launch profiles in the site computers, and the missile is typed. The information is reported to Cheyenne Mountain complex (14).

2.7.6 Human Evaluation. All of the radar sensors have several things in common. As the computers at each site determine an object will impact in the defended area, they immediately send a message to Cheyenne Mountain Complex at the same time they display it to the operators at the site. Personnel at each of the sites are assigned to monitor the equipment for these events, and are there to ensure a human or "man in the loop" is monitoring the event.

Along with the computer generated data on warning messages, each site must follow up with a voice report. The sites do what is know as "site reporting" within 60 seconds of the generation of the warning message. Site reporting is a human assessment of the event: the operators look at the equipment, the environment and personnel actions, and determine if the event (and warning message) was generated in error. This assessment is passed to the Missile Warning Center within Cheyenne mountain (14).

2.7.7 NORAD Cheyenne Mountain Complex. Cheyenne mountain is the focal point for the missile warning network. Data from all the sensors is routed over high speed circuits to a central computer system, and is processed and displayed at several centers within the mountain.

Within the mountain are several work centers related to missile warning. The primary centers are the Missile Warning Center, and the Command Post. The crew in the missile warning center receive the high speed data messages, as well as the verbal site reports. The crew then evaluates this data, along with considering other sensors with overlapping coverage, reports from IR sensors, and other data. They take all this information and pass it to the Command Director, a one star General or Admiral on crew in the Command Post (14).

The CD then determines a system report, based on all the data available. This system report reflects the CD's judgment of that particular radar system's report, and plays a part in the CINC NORAD assessment of the event. The assessment is the overall judgment of the CINC as to whether or not North America is under attack (4).

2.7.8 National Military Command Center. The system reports and the CINC NORAD assessment are passed to the National Military Command Center. The surveillance officer, who is a technician trained in the missile warning sensors, and Deputy Director of Operations (DDO), a one star general officer, on crew there will view the data received from the sites directly, and use it in conjunction with the data received from NORAD. The DDO will then contact the National Command Authorities and notify them of the situation and their options (4).

2.7.9 Decision Time. The flow of information through the network is shown in figure 2.6. It is important to note that the entire process is designed to take very little time. Even though each of the sensors detecting the event have one minute to pass a site report to the mountain, work centers within the mountain already have the data and can begin to make decisions, contact other sensors with overlapping coverage, and then use the site report as it comes in. The same process holds true for the National Military Command Center. The CINC NORAD assessment process has an established time limit, and takes place for every missile launch detected.

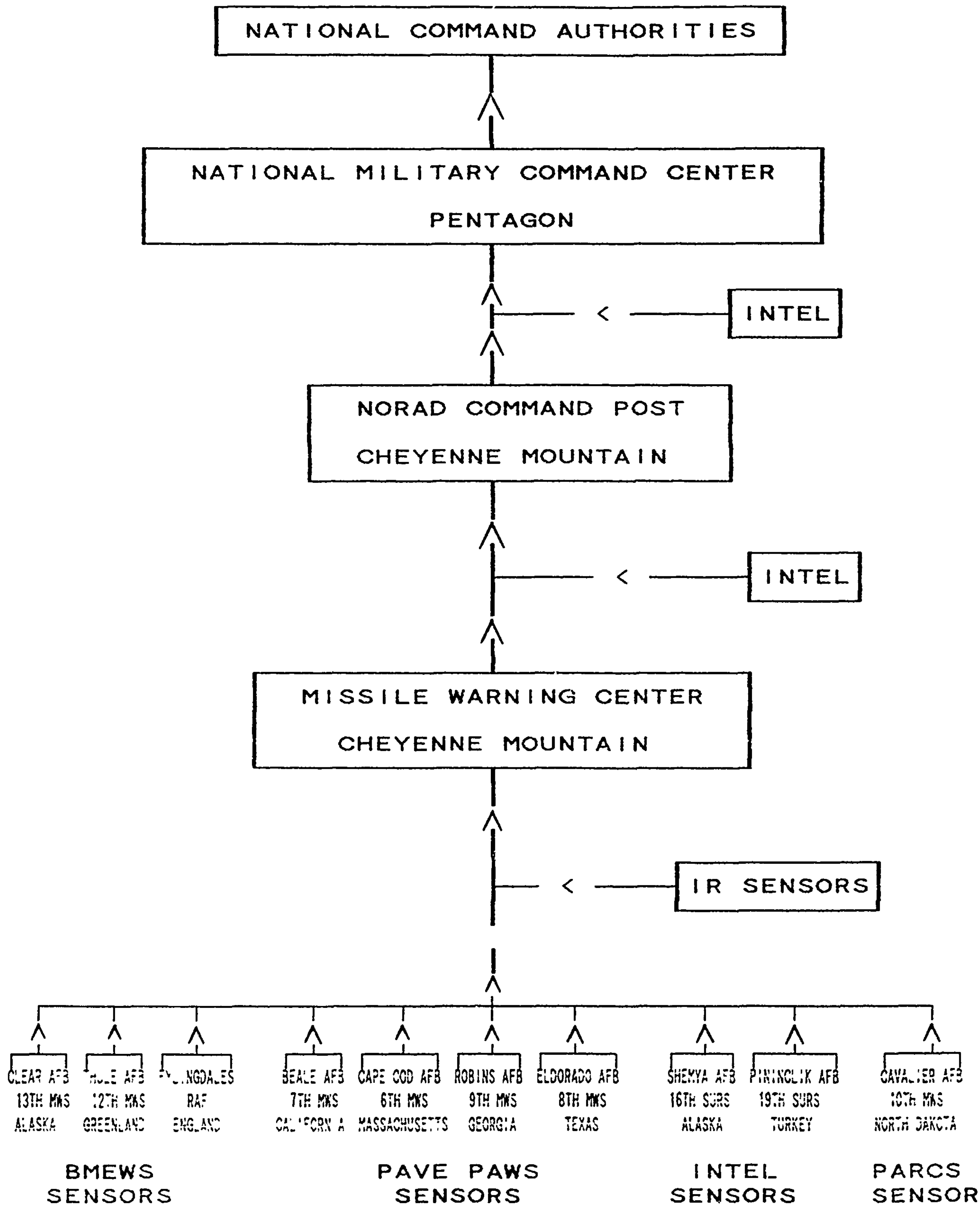


Figure 2.6. Information Flow

2.8 Summary

The philosophy behind deployment of an ABM system varies. Some possible purposes are listed below:

- A system may be designed to protect a second strike capability, therefore acting as a deterrent.
- A system may be designed to protect a given geographic region or population center.
- A system may be designed to make the enemy respond to the system, while accomplishing one or both of the above reasons.

Missile flights can be broken into four phases: boost, post-boost, mid course, and terminal. Interception is difficult in the boost and post-boost phases because of their short durations. The lengthy midcourse phase allows time for radar systems to track the missiles, calculate trajectories and predict impact points. Extensive computer processing is needed in this phase to accomplish discrimination of object types. The terminal phase is very short, lasting only from atmospheric reentry to detonation. Most dummy warheads and chaff do not survive reentry, so only warheads will survive and need to be tracked.

Past ABM systems were all discontinued before full deployment, with only the Safeguard system achieving partial deployment. Past sytems were limited by their radar, which could only track one object at a time. Newer, electronically steered radars allow systems to track multiple targets and perform discrimination functions simultaneously. Past systems used two types of interceptors: one intercepted outside the atmosphere while the missile was in the midcourse phase, the other intercepted inside the atmosphere while the warheads were in the terminal phase. The interceptors used in the Sentinel and Safeguard systems used nuclear warheads to destroy or disable their targets. The Nike- Zeus was the first system to be developed, and demonstrated that missile interception was possible. A key point is that one of the major reasons a system was never fully implemented was the perception that a ground based system could be overwhelmed by a mass attack.

Current developments have improved interceptors, using new methods to home in on the targets, and destroying them with non-nuclear warheads.

NORAD currently operates a missile warning network composed of infrared sensors and ground based radars. These sensors detect and track missile launches, and report them to the NORAD Cheyenne Mountain Complex in Colorado Springs. The Missile Warning Center and NORAD Command Post within the mountain receive and process the data from all the sensors. They quickly process the data, and pass an assessment of missile events to the National Military Command Center in the Pentagon. Crews at the Pentagon take the data, contact the National Command Authorities, and advise them of their options.

Since one purpose of this investigation is to examine the use of ABM systems to counter a Third World threat, some conclusions can be drawn from the literature about the objective of the system. Several Middle Eastern Countries, as well as Brazil and Argentina either possess or are developing missiles as well as nuclear weapons. Assuming an attack from a Third World country would be a single or small launch, the philosophy behind the system would be as an effective defensive system to destroy all incoming warheads.

III. Methodology

3.1 Introduction

This chapter will examine the methods used to solve the research questions set forth in chapter one.

3.2 Launch Locations

Three geographic regions were chosen to encompass areas considered to be possible launch locations. The regions are roughly rectangular grids, with launch points separated by five degrees in latitude and longitude. Specific known launch point coordinates were not considered, as they were encompassed by the region.

Region one covers the majority of the Middle Eastern threat. The area is defined as a block from 5 degrees to 45 degrees North Latitude, and 15 degrees to 105 degrees East Longitude. The region includes Libya, Egypt, Chad, Sudan, Turkey, Syria, Iraq, Iran, Saudi Arabia, Afghanistan, Pakistan, India, Yemen, Omen, and portions of other countries. The region is a grid of 157 launch points which are listed in table 3.1 and shown in figure 3.1.

Region two is designed to cover the Latin America region, as well as Columbia, Venezuela, Guyana, and Cuba. The area is a region from the equator to 20 degrees North Latitude, and from 55 degrees to 95 degrees West Longitude. The region is a grid of 45 launch points which are listed in table 3.2 and shown in figure 3.2.

Region three covers the remainder of the South American region. It is an area from 5 degrees to 30 degrees South Latitude, and from 55 degrees to 80 degrees West longitude. The region encompasses Peru, Bolivia, Paraguay, and parts of Brazil, Argentina, and Chile. The region is a grid of 36 points which are listed in table 3.3, and shown in figure 3.3.

N Lat	East Longitude
5°	65°, 70, 75, 80, 85
10°	15°, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105
15°	15°, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105
20°	15°, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105
25°	15°, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105
30°	15°, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105
35°	15°, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105
40°	15°, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85. 90, 95, 100, 105
45°	15°, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105

Table 3.1. Launch Area One Coordinates

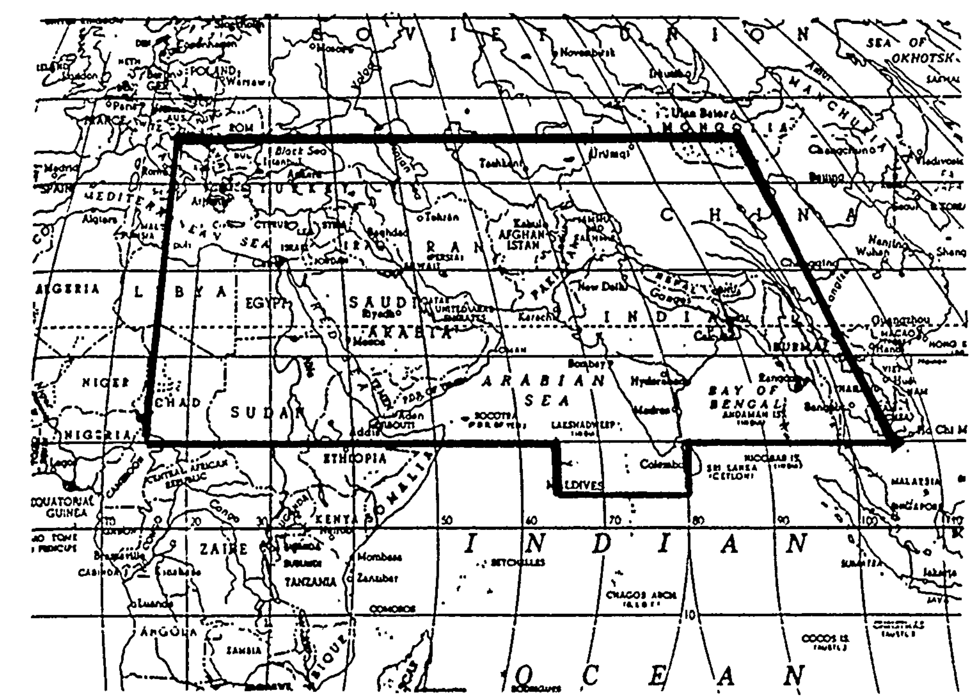


Figure 3.1. Launch Area One

N Lat	West Longitude
0°	55°, 60, 65, 70, 75, 80, 85, 90, 95
5°	55°, 60, 65, 70, 75, 80, 85, 90, 95
10°	55°, 60, 65, 70, 75, 80, 85, 90, 95
15°	55°, 60, 65, 70, 75, 80, 85, 90, 95
20°	55°, 60, 65, 70, 75, 80, 85, 90, 95
25°	55°, 60, 65, 70, 75, 80, 85, 90, 95
30°	55°, 60, 65, 70, 75, 80, 85, 90, 95

Table 3.2. Launch Area Two Coordinates

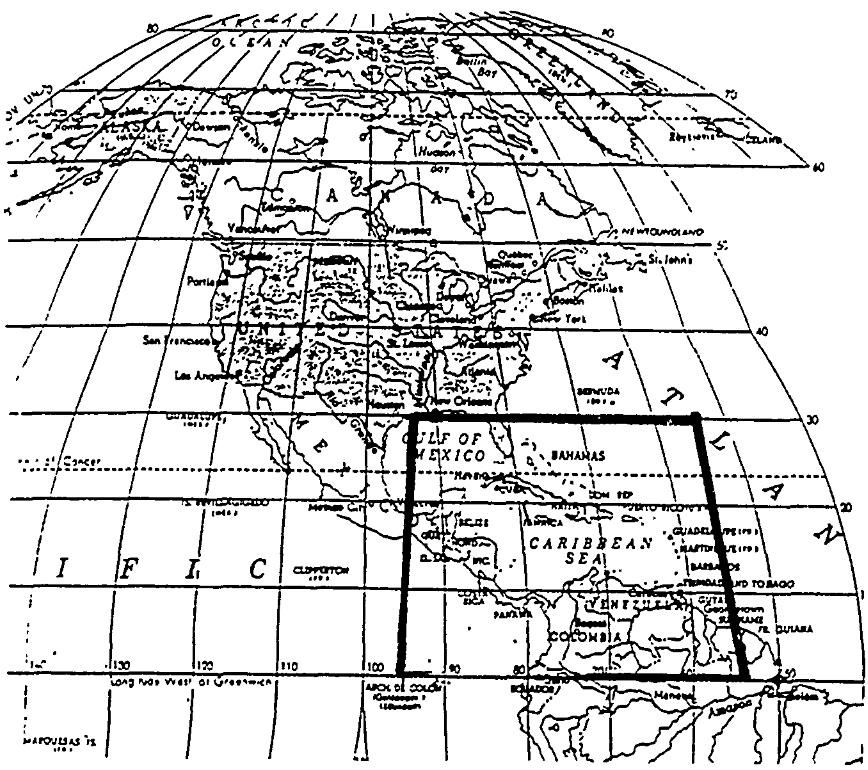


Figure 3.2. Launch Area Two

SN Lat	West Longitude
5°	55°, 60, 65, 70, 75, 80
10°	55°, 60, 65, 70, 75, 80
15°	55°, 60, 65, 70, 75, 80
20°	55°, 60, 65, 70, 75, 80

Table 3.3. Launch Area Three Coordinates

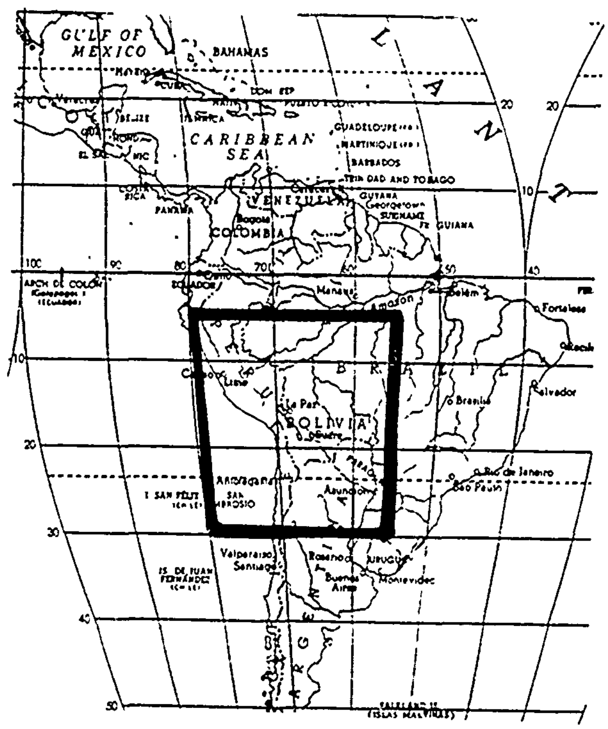


Figure 3.3. Launch Area Three

3.3 Radar Detection Modeling

The second research question of the investigation was to determine if missiles launched at the United States from the chosen launch points would be detected by missile warning radars. The network was briefly described in the literature review. After an extensive search, a model of the missile warning radar network was located at Air Force Space Command Headquarters, in the Directorate of Missile Warning, Analysis Section (DOMA).

3.3.1 Model Description. The model (COMET Program) was developed for use by NORAD in the missile warning network in the late 1970s. It was designed to be run on the NORAD Cheyenne Mountain Complex Computer System (NCS), to determine when a detected missile launch would enter radar coverage. The model has been updated many times over the years to reflect changes in radar coverage, missile types and flights, software changes, and other information. The Directorate of Missile Warning at Air Force Space Command Headquarters maintains a version of the model (12).

3.3.1.1 Hardware and Software. The program is run on a VMS system, written in FORTRAN, using common astrodynamical algorithms described in Bate, Mueller, and White's, *Fundamentals of Astrodynamics.* Each sensor in the radar network is modeled, using the range, azimuth spread, and elevation of the missile warning fan of that particular radar.

3.3.1.2 Program Description. The program begins when a launch point and an impact point are identified. The program generates an orbital element set, and then a trajectory for the missile. The program compares the trajectory to the given coverage of each radar sensor to determine if it will enter coverage (12).

3.3.1.3 Defended Area. Often when the program is used, a launch point may be known, but no specific impact point determined (12). In this case, the model may use a standard defended area to model the continental United States and Southern Canada. The defended area is a grid of 50 points as shown in figure 3.4. For this investigation, the program was run using the given launch point against each of the 50 impact points.

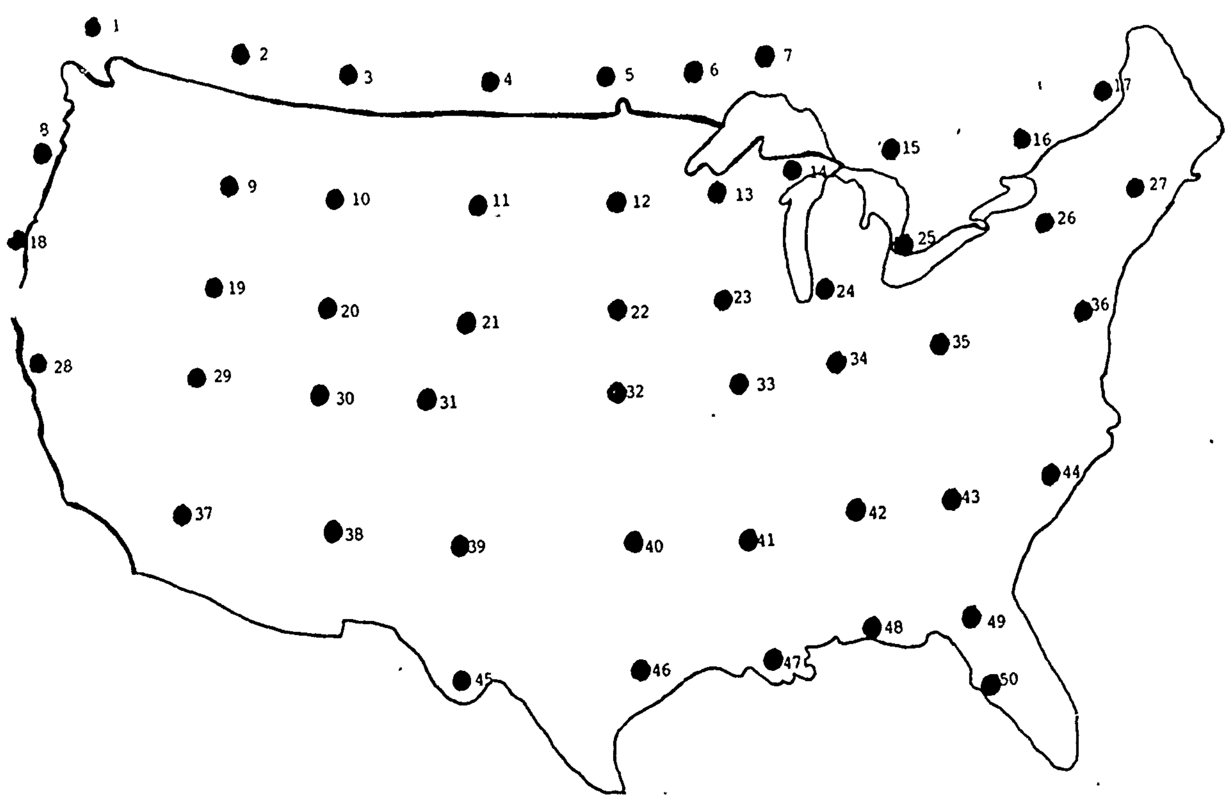


Figure 3.4. Defended Area Points

3.3.1.4 Model Validation. The model has been in use for many years in the NORAD computer system, and has been validated numerous times. The most recent form of validation was completed in November of 1989. The MITRE corporation was tasked to determine if the algorithms used in the model were accurate and logically sound. They concluded the model was accurate, and suitable for use in the missile warning network (12).

3.3.1.5 Missile Type. The model has the capability of computing orbital element sets for various known missile types, and their respective trajectories. Since this investigation assumed launches from Third World locations would be of minimum energy trajectory, the model was run using a generic missile type with a minimum energy trajectory. The minimum energy trajectory provides the maximum range for a given booster's energy capability. While it is possible for Third World countries to develop lofted or depressed trajectories, there is no evidence they currently possess the capability, and they will not be considered here.

3.3.1.6 Output. The output from the model is grouped into records. Each record represents a specific launch point, a specific impact point, and a specific radar sensor's coverage. Since the investigation used 238 launch points, running each against the 50 impact points and 14 sensors, 166,600 records were created. Each record gives the time of entry into radar coverage, the length of time in coverage, the impact time, and various other data. The records were output to 6250 bit per inch magnetic tape. The tapes were then transported from Colorado Springs to AFIT, where a FORTRAN program was written to extract those records which contained a detection by a radar sensor.

3.3.2 Adequacy of Model. As can be seen from the description of the model, the Comet program is very complete. Since the model is based on the current missile warning network, it fits into the objective of this investigation very well. The model does not currently use the radars at Pirinclik or Fylingdales, as they are not often in an operational mode which would provide warning against an attack against the US. When the new phased array radar at Fylingdales is completed, it may offer more detection capability for launches against the US, and then consideration should be given to adding it to the model. There may be certain aspects of the model which would have to be further examined if the results were to be used in a technical investigation, but for the purpose of this investigation the model is very adequate.

3.3.3 Analysis of Model Results. The output from the model was loaded into computer files, separated by launch region. Several types of analysis were performed on the data.

- Each launch location was examined to determine if the launch would be detected by a radar. If no detection occurred, some limited analysis was completed to determine the reason, if possible.
- A subsection of the Middle Eastern launch region was defined, and analyzed to determine the warning times provided for an attack against the US. Nine launch points were statistically compared to establish the minimum, maximum, and mean warning time provided to each of the fifty impact points.
- A subsection of launch area two was defined, and analyzed to determine the warning times against the southern US. The four launch points closest to the US were analyzed to determine mean and minimum warning times to the eleven most southern impact points in the US.

3.4 ICBM Flight Phases Relevant to the Investigation

The literature review discussed the phases an ICBM goes through during its flight. The objective of this section was to determine the best possible phase, or time and location, for interception.

In order to intercept incoming missiles with minimum modifications to the existing missile warning network, it was assumed no attempt at interception will be made until the radar network has detected, and is tracking, the incoming missiles.

The data from the Comet program was used to determine which phase of flight the missiles were in when detected, and in which phase interceptions could be made.

It may be assumed that launches will be detected almost immediately by IR sensors, but the data from these sensors is currently insufficient to track a missile in ballistic flight, and so they were not considered in this phase.

3.5 Interception and Interceptor Selection

The fourth research question deals with methods of interception. The literature review touched on the past interceptors, as well as current research efforts. In order to determine a suitable interceptor, the time available for intercept was assumed to be the same as the warning time provided by the Comet program. Time was also allowed for the communication of the event, and decision time by authorities.

Given the above information, it was determined that interceptors based outside the United States would not be considered. While it is possible for a European based interceptor to destroy a missile at an earlier time, the time needed to make the decision to launch, as well as political considerations, would make the interception from outside the US impractical.

The various programs in current development were examined to see which interceptors could be used, given the warning times provided, and the command and control actions required. A network of interceptors designed to cover the entire continental US was examined.

3.6 Network Modifications

Using the Missile Warning structure detailed in the Literature Review, a basic architecture was established for a possible ABM network. The structure was intended to be a minimum modification of the existing network. Assumptions were stated regarding the chain of command and operational responsibilities. It was assumed the ABM system would be tied into the current network, and fall under the same major command. Finally, a chart was designed to graphically represent the entire process, from missile launch through interception and follow on actions.

IV. Computer Model Results

4.1 Introduction

This chapter presents the analysis of results from the COMET program described in Chapter III. The model provided information about the ability of the current missile warning network to detect missile launches, and the warning time provided after detection. The chapter details the results of each of the three launch areas, and provides a more in depth analysis of a smaller sample area within the Middle Eastern launch area.

4.2 Objective

The first objective of the investigation was to determine if launches against the US could be detected by the present missile warning network. The computer model described in Chapter III was used to make this determination through the following actions:

- Each of the launch points provided is run against each of the fifty points representing the defended area. The program processes fifty launches from each location.
- The trajectory for each of the launches is determined, and evaluated to determine if radar interception will take place.
- The trajectory for each launch is evaluated for each sensor in the network. Dual faced sensors such as PAVE PAWS and Thule count as two sensors, giving the network a total of fourteen sensors.
- The model creates a data record for each of the evaluations, so 700 records are created for each launch point.

4.3 Computer Model Output

As stated in Chapter III, the Comet model is maintained at Air Force Space Command Headquarters, at Peterson AFB, CO. Space Command personnel executed the model on the 256 launch points used in this investigation. The output was loaded onto magnetic tape and transported to AFIT.

A small sample of the output is shown in figure 4.1. A slightly reduced copy of the headings and five sample data records are included in the sample. As described earlier, the model creates fourteen records, one for each sensor, for every simulated launch. The records shown in figure 4.1 are the first five records for a launch from 15 degrees North, 55 degrees East (305 degrees West), to an impact point of 50 degrees North, 124 degrees West. In the sample shown, only the second and fifth records show a radar detection.

By examining the fields within a record, the times from launch to detection, and from detection to impact for each sensor can be established. In the second record, sensor number 384 would detect the launch 511 seconds after launch, and 1420 seconds before impact.

```
                                     SUMMARY DATA INDEX
1  EVENT       LAUNCH     LAUNCH     IMPACT     IMPACT     SEM MAJ      ECCN   APOGEE     MISL
1   NO.         LAT        LONG       LAT        LONG       AXIS               HEIGHT     TYPE
1              (DEG)      (DEG)      (DEG)      (DEG)       (ER)                (NM)

2  ENTER      TIME      AZIMUTH    ELEVATN     RANGE     ECCNTRIC   TIME TO    SENSOR  M
2            (SEC)       (DEG)      (DEG)       (NM)      ANOMALY    IMPACT      NO.
2                                                          (DEG)      (SEC)

3 REPORT      TIME      AZIMUTH    ELEVATN     RANGE     ECCNTRIC   TIME TO    FLIGHT  M
3            (SEC)       (DEG)      (DEG)       (NM)      ANOMALY    IMPACT     TIME
3                                                          (DEG)      (SEC)     (SEC)

4  EXIT       TIME      AZIMUTH    ELEVATN     RANGE     ECCNTRIC   TIME TO     MISL   M
4            (SEC)       (DEG)      (DEG)       (NM)      ANOMALY    IMPACT     CAP
4                                                          (DEG)      (SEC)

5  R&S        TIME     ECCENTRIC    TIME     ECCENTRIC   ETHFXT    INERTIAL    SENS
5            (SEC)      ANOMALY    (SEC)      ANOMALY    AZIMUTH    AZIMUTH    COVRG
5                        (DEG)                 (DEG)      (DEG)      (DEG)

6 BURNOUT     TIME       GAMMA      GAMMA       RV LAT    RV LON       RRV        RV AZ       RVV
6            (SEC)      ETHFXT    INERTIAL       GEOC     (DEG)       (NM)       INERT    (NM/SEC)
6                        (DEG)      (DEG)       (DEG)                            (DEG)

7           V ETHFX     V INER    GRND RNG    FLT RNG,      AZ         ELV
7           NM/SEC      NM/SEC       NM          NM        RATE        RATE
                                  ESTIMATE    ESTIMATE   DEG/SEC    DEG/SEC

                      SAMPLE OUTPUT FROM FIVE DATA RECORDS

1   1-   1      5.000    305.000     50.000    236.000    0.77155    0.59888    804.53       5
2  ENTER      0.      0.000      0.000      0.000      0.000     1932.       383.
3 REPORT      0.      0.000      0.000      0.000      0.000     1932.      1932.
4  EXIT       0.      0.000      0.000      0.000      0.000     1932.      PASS
5  R&S      582.    147.560     1792.     229.759    -41.032    -37.543    OUT
6 BURNOUT   267.     30.219     31.644      9.346    -58.417   3558.595    -37.543       3.413
7             3.56      3.41    4372.88    4072.78     0.0000     0.0000

1   1-   1      5.000    305.000     50.000    236.000    0.77155    0.59888    804.53       5
2  ENTER    451.    131.236      2.700   1526.918    138.266     1480.       384.  S
3 REPORT    511.    131.493      8.368   1407.409    142.568     1420.      1932.  T
4  EXIT     961.    140.828     70.849    800.697    173.030      970.      PASS   T
5  R&S      421.    136.082     1708.     223.499    -41.032    -37.543    IN
6 BURNOUT   267.     30.219     31.644      9.346    -58.417   3558.595    -37.543       3.413
7             3.56      3.41    4372.88    4072.78     0.0188     0.1336

1   1-   1      5.000    305.000     50.000    236.000    0.77155    0.59888    804.53       5
2  ENTER      0.      0.000      0.000      0.000      0.000     1932.       385.
3 REPORT      0.      0.000      0.000      0.000      0.000     1932.      1932.
4  EXIT       0.      0.000      0.000      0.000      0.000     1932.      PASS
5  R&S      421.    136.082     1708.     223.499    -41.032    -37.543    OUT
6 BURNOUT   267.     30.219     31.644      9.346    -58.417   3558.595    -37.543       3.413
7             3.56      3.41    4372.88    4072.78     0.0000     0.0000

1   1-   1      5.000    305.000     50.000    236.000    0.77155    0.59888    804.53       5
2  ENTER      0.      0.000      0.000      0.000      0.000     1932.       386.
3 REPORT      0.      0.000      0.000      0.000      0.000     1932.      1932.
4  EXIT       0.      0.000      0.000      0.000      0.000     1932.      PASS
5  R&S      455.    138.515     1653.     219.546    -41.032    -37.543    OUT
6 BURNOUT   267.     30.219     31.644      9.346    -58.417   3558.595    -37.543       3.413
7             3.56      3.41    4372.88    4072.78     0.0000     0.0000

1   1-   1      5.000    305.000     50.000    236.000    0.77155    0.59888    804.53       5
2  ENTER    485.    170.823      2.239   1643.376    140.674     1447.       387.  S
3 REPORT    545.    174.632      6.710   1557.411    144.931     1387.      1932.  T
4  EXIT    1055.    232.116     31.378   1233.692    179.161      877.      PASS   T
5  R&S      455.    138.515     1653.     219.546    -41.032    -37.543    IN
6 BURNOUT   267.     30.219     31.644      9.346    -58.417   3558.595    -37.543       3.413
7             3.56      3.41    4372.88    4072.78     0.1075     0.0511
```

Figure 4.1. Sample Output

Since the total output of the 3 launch areas was 166,600 of the records described above, it was necessary to reduce the output to a more workable form. A FORTRAN program was written to limit the output. The program screened out those records with no sensor intercept, as they contained no useful data. It also reduced the output of those with intercepts to the top two lines of the intercept record. The magnetic tapes were read onto disc storage on the AFIT computer network, where they could be accessed through the Hercules VMS system, and the FORTRAN program executed. Each of the launch areas were run on the model separately, resulting in three files. The files were edited to remove the headings and other extraneous information, leaving only the intercept records. The FORTRAN program used to reduce the output is shown in Appendix A. The three original output records were maintained for further investigation, which will be described later.

The output was then analyzed to determine if each launch was detected by at least one sensor. Other data, such as times to impact were further screened and statistical information compiled. The results of the process is presented in the following sections.

4.4 Launch Area One Results

Launch area one was designed to encompass a large share of the Middle East. As pointed out in Chapter III, area one consists of 147 launch points. Since the model evaluates each of the launch points against the 50 impact points, it produces a total of 7350 launches from this region.

Upon initial examination of the output, there were 302 of the 7350 launches that were not detected by any sensors. Further examination revealed all of the undetected launches were long range flights. Analysis detailed in Appendix B shows the range was beyond the capability of the missile type used in the model. Discussion with personnel at Space Command headquarters confirmed that a launch with a flight range beyond that of the missile type used in the model will not show a radar detection.

Some simple assumptions can be made about the undetected launches:

1. Since the range was beyond the capability of Soviet SS-11, SS-13, and SS-18 missiles, it is not unreasonable to assume a Third World country would not have the technology to develop a missile with such range in the near term.
2. If the missile capability did exist, the azimuths of these launches would be within the same range of azimuths of the launches that were detected.
3. Since the azimuths of the undetected launches would fall within the range of detected launches, it can be assumed they would be detected by the sensor network.
4. The warning time provided by the sensors for these launches would be at least as great as those detected, since the flight time is longer.

It appears that virtually all of the launches from the Middle East region would be detected by the current radar network. Further analysis of the results, regarding warning times, is covered in section 4.5.

4.4.1 Middle Eastern Area Sample Warning Times. In order to more closely examine the results, a smaller sample of the output was examined. A small, centrally located region in the Middle Eastern area was selected. The region is a grid of 9 launch points, from 30 to 40 degrees North Latitude, and 35 to 45 degrees East Longitude. The area is depicted in figure 4.2. The intent of the sample was to condense the data, and determine results typical of the entire region. While the shortest flight times are not necessarily from the sample region, the area could be considered a high threat region. Short flight times, and the resulting warning times will be discussed later.

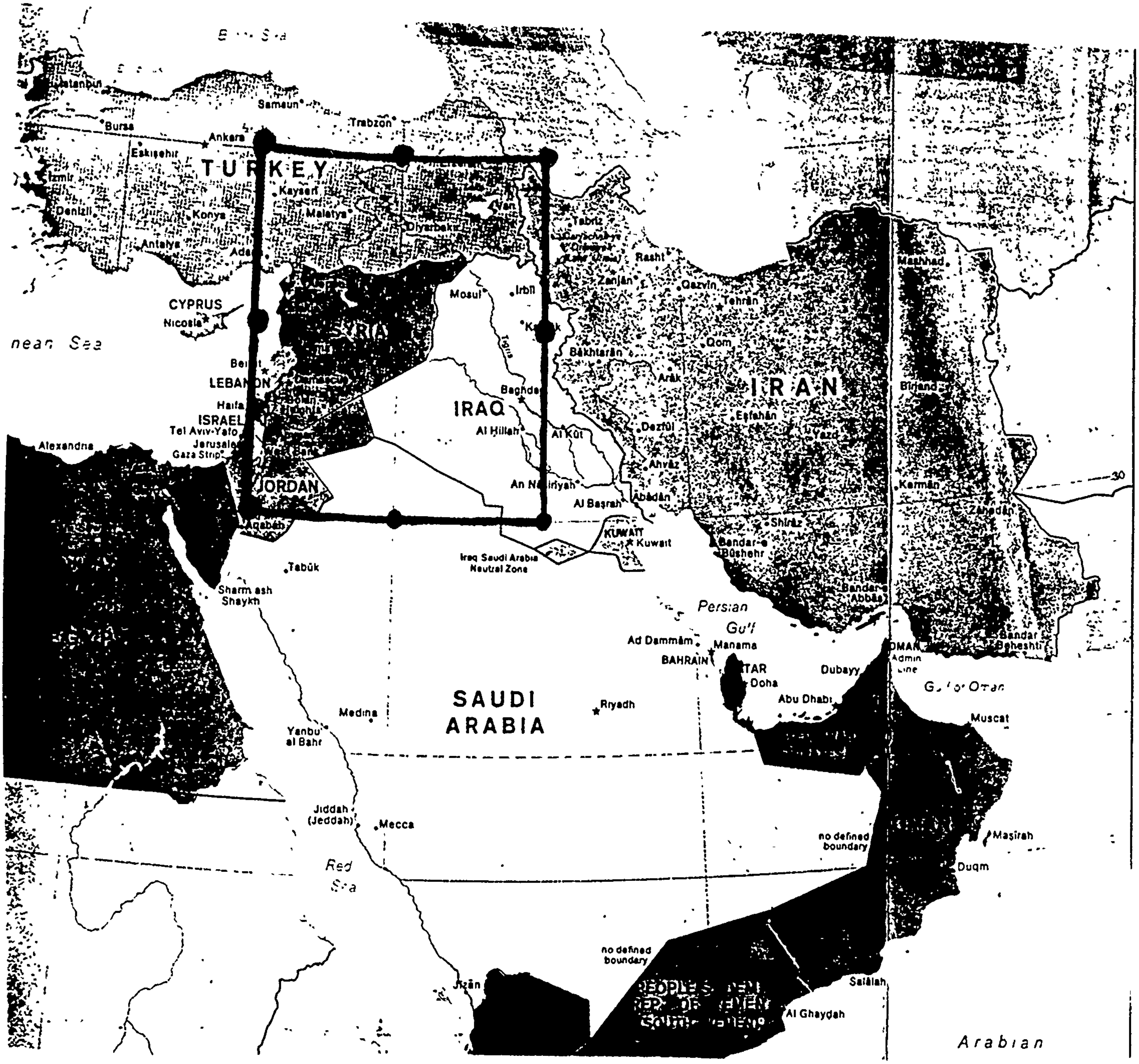


Figure 4.2. Sample Launch Area

To establish the typical or average warning time the US would have of launches from this area, the first and second radar detection times were compiled from each of the nine launch points to each of the fifty defended area impact points. Data from the nine points was grouped together, representing one launch area. These times were compiled from manually screening the output provided by the model.

The times from each of the nine launch points were treated as random samples from the area, and a mean warning time and its standard deviation, the minimum warning time, and maximum warning time were computed. The data is displayed in tables 4.1 and 4.2. The results of the computations show the expected warning times for each of the impact locations from the general launch area.

The results of the computations have been graphically depicted in figures 4.3 through figure 4.6. Figure 4.3 shows the impact area map with the minimum warning time (in seconds) provided for launches from the sample Middle East launch area to each impact point, based on the first radar detection. Figure 4.4 shows the minimum warning times provided after a second sensor has detected the launch. Using the SAS statistical program, a three dimensional plot was generated for the warning times. The axes of the plot represent the latitude longitude grid of the US. Figure 4.5 shows the plot of the warning times after the first sensor detects the launch, fig 4.6 shows the warning times after the second sensor detection. The graph does not take into account the difference in grid size as latitude changes, but gives a fair approximation of the data. The graphs are slightly distorted from using a rectangular grid to represent the US. The program extrapolates values for all regions, and since there is no data for regions outside the US but still on the grid, the resulting time values are lowered. These distortions occur along the edges of the US.

Impact Point	Minimum Warning Time	Maximum Warning Time	$\bar{X}$	S
1	1527	1536	1531.78	2.86259
2	1493	1511	1504.67	5.80948
3	1446	1482	1467.89	11.97340
4	1378	1445	1416.67	20.95830
5	1311	1398	1356.56	26.68380
6	1267	1367	1318.33	30.74900
7	1199	1314	1263.22	35.71690
8	1585	1595	1591.00	3.46410
9	1543	1572	1560.67	9.12414
10	1490	1541	1519.33	15.70030
11	1417	1500	1464.00	25.88400
12	1342	1449	1398.11	32.83460
13	1284	1415	1354.11	38.22450
14	948	1358	1294.78	43.40730
15	1136	1306	1229.89	52.43910
16	1028	1234	1140.67	63.46060
17	949	1083	1070.89	69.60500
18	1636	1653	1646.89	5.81903
19	1589	1629	1613.33	12.39960
20	1521	1596	1566.67	22.43880
21	1450	1551	1506.33	32.22580
22	1362	1507	1441.67	43.66920
23	1303	1459	1386.33	46.98940
24	1066	1399	1285.89	97.68630
25	1128	1306	1244.00	66.10000
26	1027	1269	1161.89	75.16720
27	900	1198	1062.11	92.68820
28	1670	1704	1690.78	10.76780
29	1632	1685	1659.56	18.38550
30	1557	1648	1610.44	28.66670
31	1495	1603	1555.22	34.40120
32	1376	1540	1463.89	49.54660
33	1306	1490	1410.11	57.22420
34	1222	1435	1337.33	65.86160
35	1108	1372	1252.56	81.28210
36	987	1288	1155.89	92.91180
37	1669	1737	1708.78	20.99870
38	1587	1697	1651.78	34.24830
39	1490	1645	1573.33	51.63570
40	1376	1580	1487.78	62.22500
41	1308	1527	1429.78	69.27980
42	1191	1467	1343.11	85.02560
43	1077	1389	1244.11	101.02200
44	1010	1318	1156.33	109.11900
45	1504	1687	1605.00	56.67890
46	1365	1606	1503.89	75.67600
47	1275	1559	1435.67	89.08420
48	1176	1478	1341.56	96.96530
49	1098	1404	1234.78	107.98900
50	1103	1387	1204.56	102.46600

Table 4.1. Times Until Impact From First Radar Detection

Impact Point	Minimum Warning Time	Maximum Warning Time	$\bar{X}$	S
1	554	899	698.00	157.4820
2	721	1000	863.44	99.0380
3	835	1018	922.00	64.3409
4	863	1001	929.44	49.9928
5	854	965	910.22	39.6240
6	849	937	891.00	31.7017
7	821	895	856.11	27.2050
8	653	1066	887.67	152.3930
9	897	1115	1006.44	77.1704
10	961	1112	1036.89	54.6751
11	979	1098	1034.11	42.1884
12	962	1055	1005.44	39.5004
13	943	1024	980.33	30.4138
14	911	977	940.00	26.4055
15	866	922	892.67	21.3951
16	816	857	839.22	14.7036
17	747	788	817.22	142.3520
18	904	1187	1047.89	101.7560
19	1030	1206	1117.56	64.3178
20	1072	1206	1136.11	48.5501
21	1072	1175	1123.89	37.8432
22	1079	1142	1109.56	24.2802
23	1037	1091	1062.67	21.7025
24	945	996	1019.33	17.4069
25	945	986	968.44	14.8165
26	876	927	904.22	18.3901
27	807	849	830.67	12.9711
28	1076	1284	1184.11	74.7219
29	1139	1298	1216.11	57.7807
30	1182	1281	1224.67	40.9878
31	1149	1239	1193.44	37.8790
32	1136	1189	1162.00	21.3307
33	1106	1150	1130.11	17.7161
34	1059	1101	1082.89	14.8108
35	1004	1046	1027.44	13.2109
36	927	970	951.11	13.3645
37	1240	1372	1301.56	52.8562
38	1254	1349	1301.33	34.8891
39	1242	1313	1048.75	32.3844
40	1201	1256	1226.89	19.4258
41	1166	1210	1190.89	15.3496
42	1115	1160	1139.67	13.9374
43	1045	1101	1076.67	18.6346
44	604	1049	937.56	184.8910
45	1309	1370	1337.44	24.2750
46	1267	1314	1288.79	20.5595
47	1220	1270	1248.44	18.6555
48	1147	1200	1174.89	18.1276
49	744	1124	1073.00	125.0400
50	744	1156	1052.11	183.4980

Table 4.2. Times Until Impact From Second Radar Detection

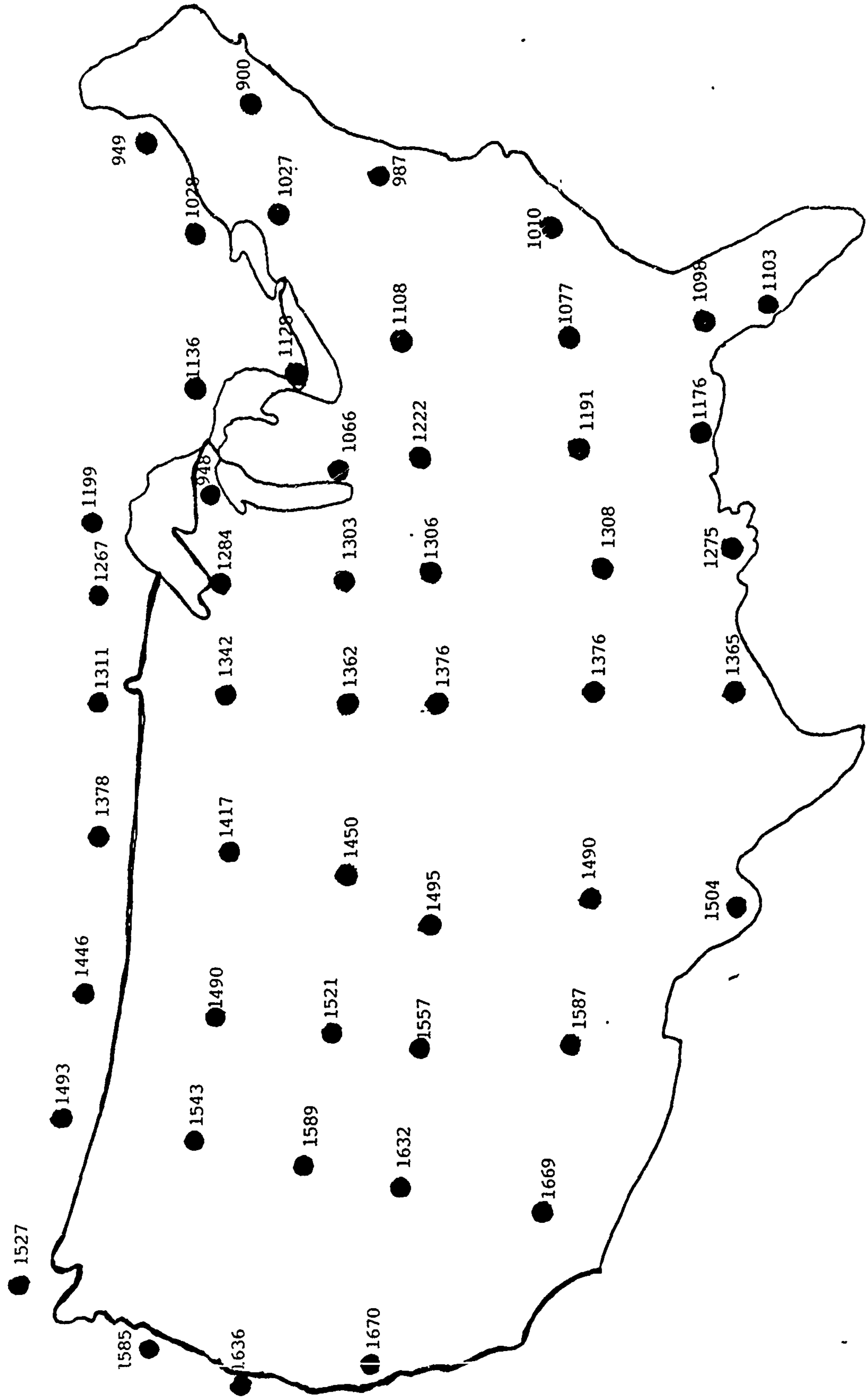


Figure 4.3. Warning Times From Middle East Sample Region Based on First Radar Detection (Seconds Until Impact)

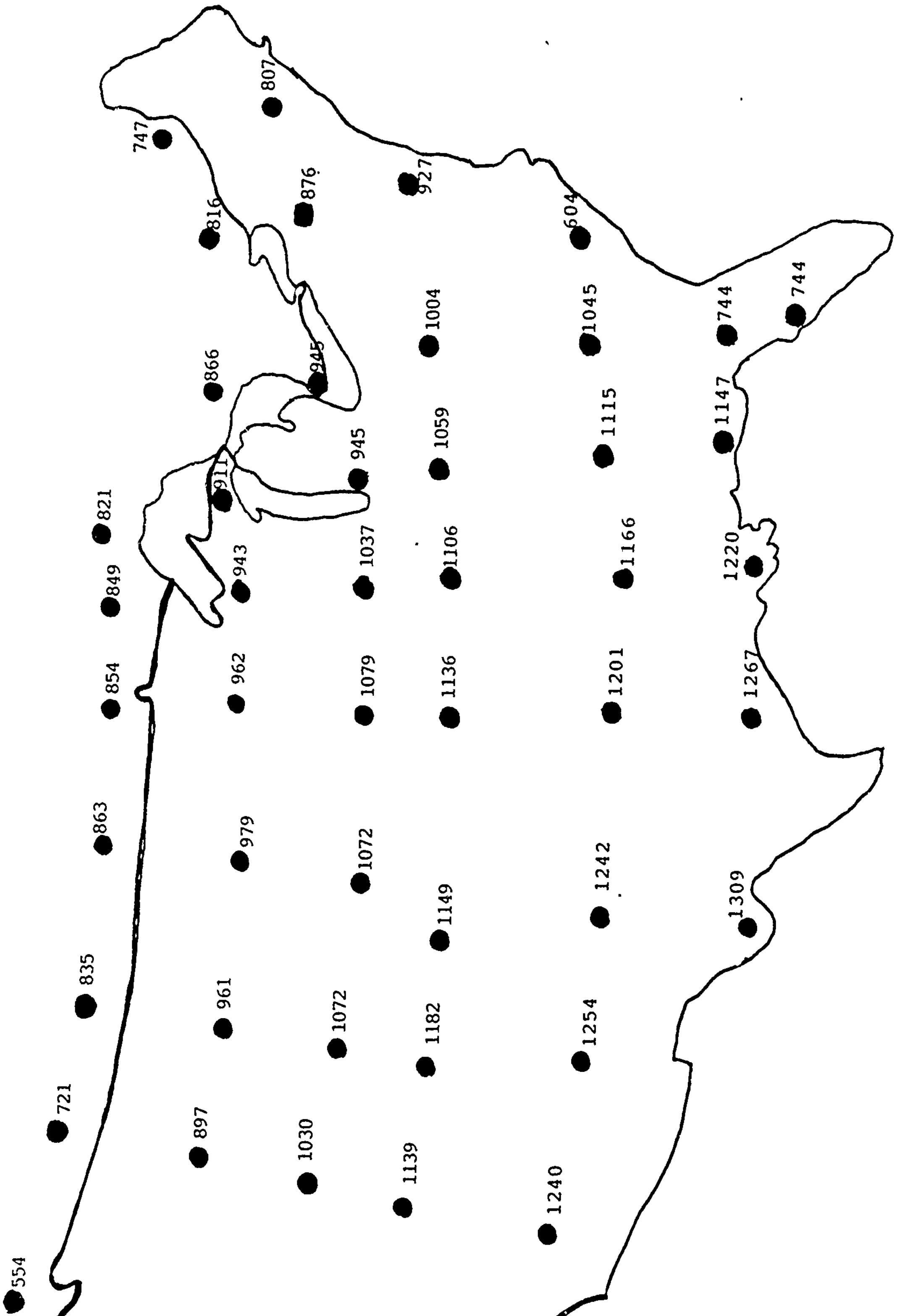


Figure 4.4. Warning Times From Middle East Sample Region Based on Second Radar Detection (Seconds Until Impact)

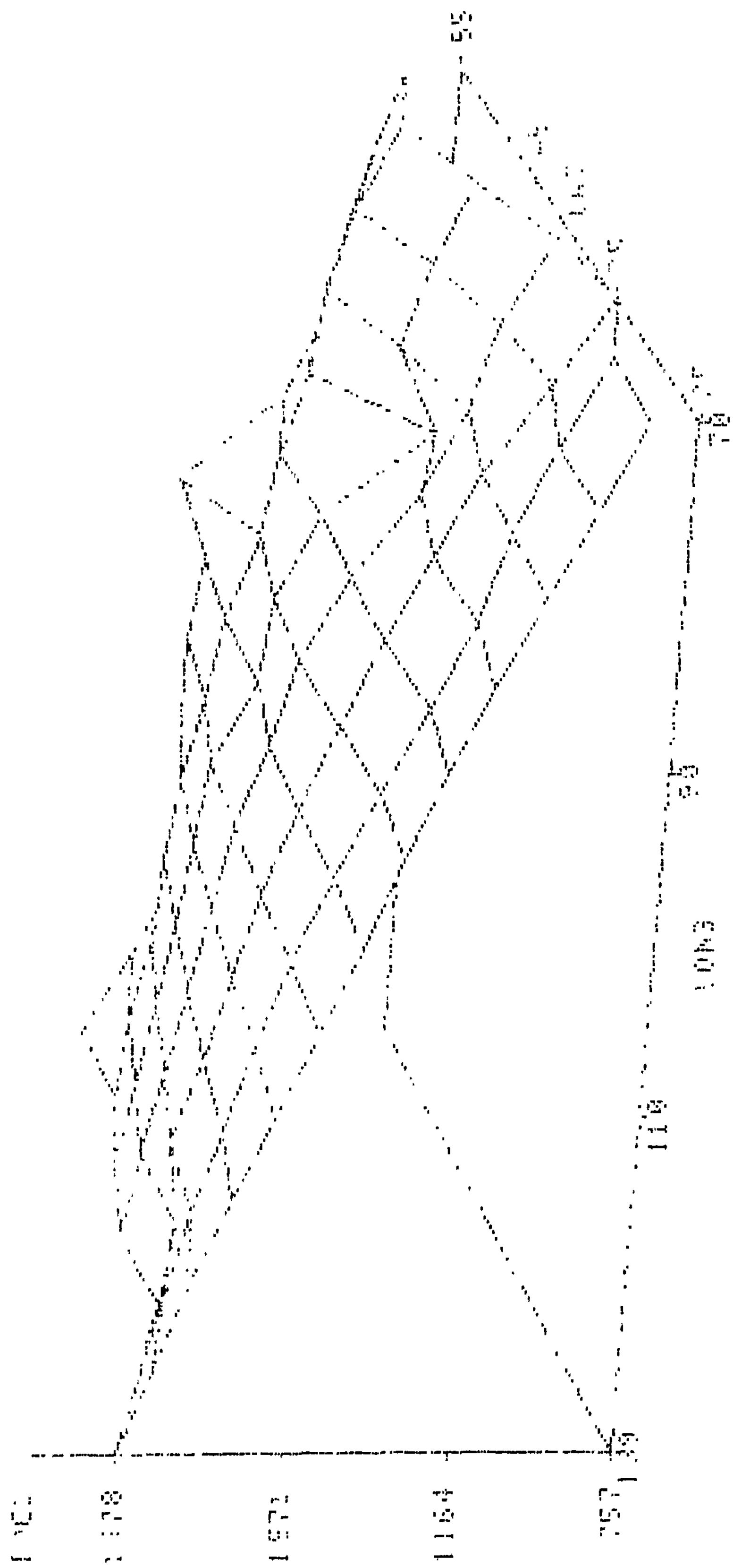


Figure 4.5. Warning Times From Middle East Sample Region Based on First Radar Detection (Seconds Until Impact)

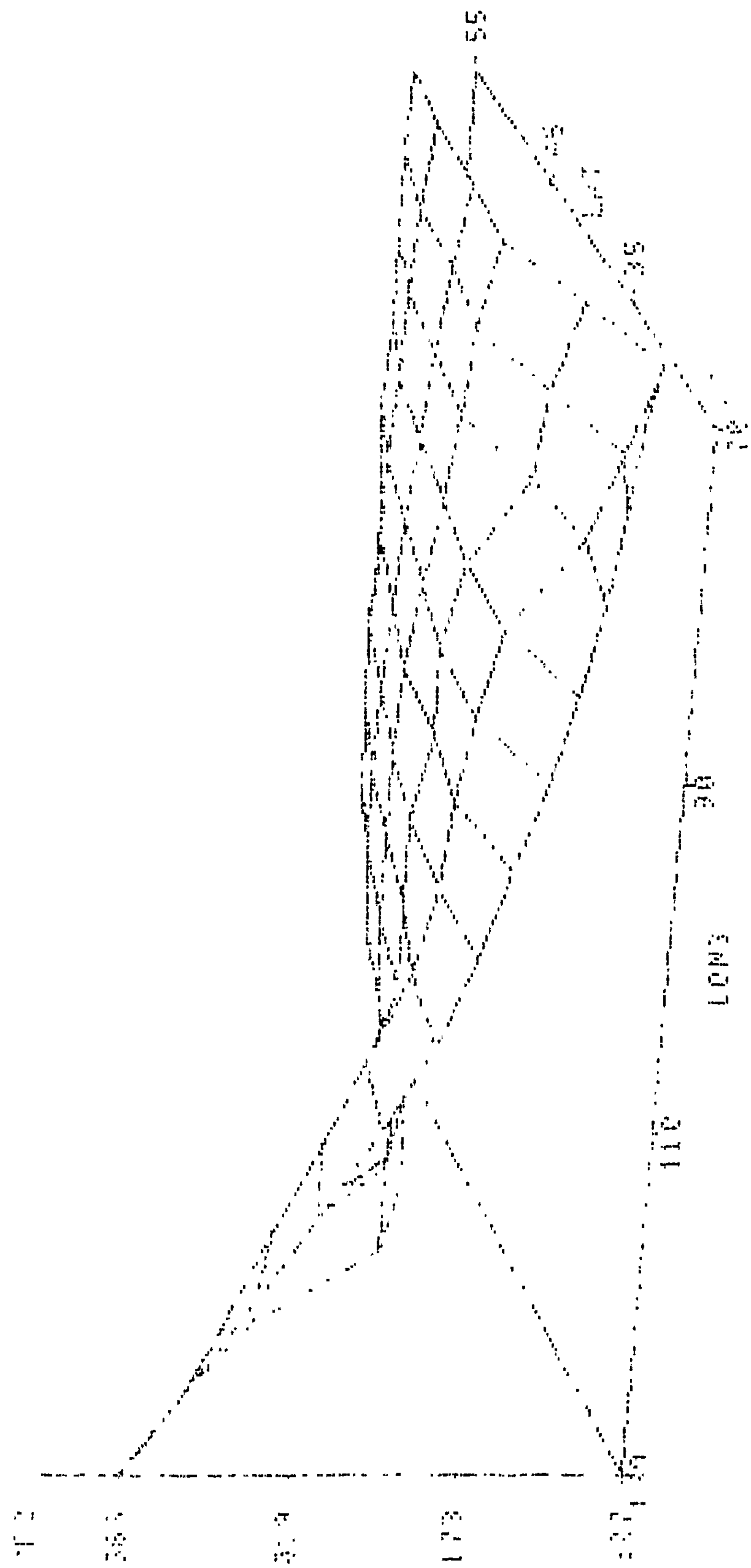


Figure 4.6. Warning Times From Middle East Sample Region Based on Second Radar Detection (Seconds Until Impact)

4.4.2 Middle East Launch Area Warning Times. A prime concern is the warning time provided for launches from the Middle East. The sample above shows warning times for a small region. The output from the entire Middle Eastern launch area was screened to determine minimum warning times. Not surprisingly, the minimum warning times were noted where the flight times were the shortest. No warning time under 800 seconds was observed.

4.5 Launch Area Two Results

Launch area two encompassed the part of the Latin American area north of the equator. This area contained 45 launch points, resulting in 2250 launches. The initial analysis of the output revealed 24 of the 2250 launches were not detected. Further examination revealed that virtually all of the undetected launches were at extremely short ranges. It was concluded that a missile type problem similar to that described in launch area one occurred in this region also. The missile type used in the model had a minimum range greater than the distance of the closest launch and impact points.

While the use of the particular missile type does eliminate some of the output data needed, the results are still useful. While there is little doubt a missile with a shorter range could easily be developed, it appears the results of the model are adequate for the following reasons:

- When the area was described as a grid of launch points, it was designed to encompass an entire area. That area included those points located over water.
- Most of the undetected points were in the northern area of the region, and were actually ocean areas. The points containing Cuba, and areas further south did produce good results.
- Those launches that were undetected would fall within the same range of azimuths of those that were detected, and should therefore also be detected.

Since this area is considerably smaller than launch area one, no sample area was used. The primary concern for this area is warning time provided, so the analysis centered on those points closest to the US. Data from four launch points was compiled, and a minimum time of detection to a region in the US determined. The region in the US was defined as the 11 closest impact points. The launch and impact points are shown in figure 4.7. The results of the analysis are displayed in table 4.3.

An obvious conclusion is the warning time provided against launches from this area is significantly less than the Middle East, but the time between first and second sensor detection is less. Treating the four launch points as one area and the eleven impact points as one area, general statistics were compiled. The minimum time before the first radar detection was 485 seconds, the maximum 836, and the mean 619. The minimum time before the second radar detection was 336 seconds, the maximum 741, and the mean 537.

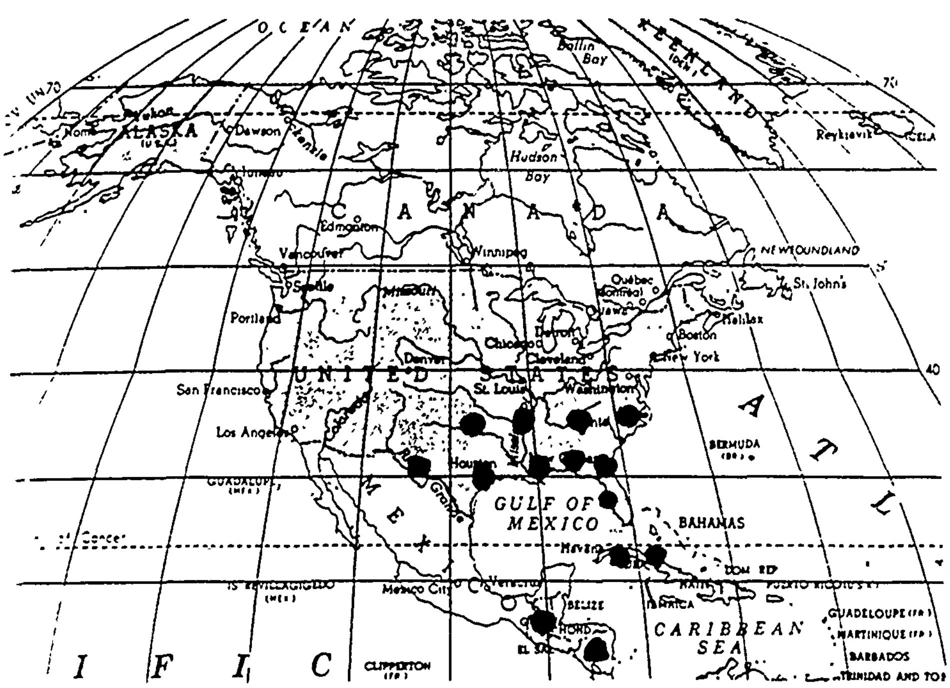


Figure 4.7. Sample Launch and Impact Areas

IMPACT LOCATION	LAUNCH LOCATION		**Earliest Detection** Time to Impact	**Second Detection** Time to Impact
N34 / W96	Nicaragua	N15/W85	689	656
	Guatemala	N15/W90	647	629
Southern	Cuba	N20/W75	758	636
Oklahoma	Cuba	N20/W80	694	614
N34 / 92	Nicaragua	N15/W85	660	619
	Guatemala	N15/W90	630	619
Eastern	Cuba	N20/W75	698	561
Arkansas	Cuba	N20/W80	640	538
N34 /W87	Nicaragua	N15/W85	643	579
	Guatemala	N15/W90	630	629
Northern	Cuba	N20/W75	628	478
Alabama	Cuba	N20/W80	586	463
N34 / W82	Nicaragua	N15/W85	649	573
	Guatemala	N15/W90	672	654
Eastern	Cuba	N20/W75	572	427
Georgia	Cuba	N20/W80	557	382
N34 / W78	Nicaragua	N15/W85	672	586
	Guatemala	N15/W90	711	688
Western	Cuba	N20/W75	544	405
N Carolina	Cuba	N20/W80	559	387
N30 / W103	Nicaragua	N15/W85	685	675
	Guatemala	N15/W90	629	582
Southwest	Cuba	N20/W75	836	741
Texas	Cuba	N20/W80	757	691
N30 / W96	Nicaragua	N15/W85	592	568
	Guatemala	N15/W90	547	525
Southeast	Cuba	N20/W75	714	587
Texas	Cuba	N20/W80	635	540
N30 / W92	Nicaragua	N15/W85	552	506
	Guatemala	N15/W90	522	510
Southwest	Cuba	N20/W75	642	495
Louisiana	Cuba	N20/W80	566	453
N31 / W87	Nicaragua	N15/W85	554	494
	Guatemala	N15/W90	551	540
Northwest	Cuba	N20/W75	572	364
Florida	Cuba	N20/W80	566	453
N31 / W82	Nicaragua	N15/W85	562	474
	Guatemala	N15/W90	593	571
Northern	Cuba	N20/W75	487	-
Florida	Cuba	N20/W80	-	-
N28 / W81	Nicaragua	N15/W85	485	336
	Guatemala	N15/W90	534	504
Southwest	Cuba	N20/W75	-	-
Florida	Cuba	N20/W80	-	-

Table 4.3. Launch Area Two Detection Times

4.6 Launch Area Three Results

Launch area three contained the portion of the Latin American area south of the equator. There were 36 launch points evaluated against each of the 50 impact points, resulting in 1800 launches. Virtually all of the 1800 launches were detected by the missile warning network. Since the warning times provided for all of these launches was greater than those in the area north of the equator, no further analysis was attempted.

V. ABM System Design

5.1 Introduction

This chapter uses the results of the computer model described in Chapter IV and the information detailed in the Literature Review to suggest a possible ABM system. One of the objectives of this investigation was to determine how an ABM capability could be incorporated into the current missile warning network with minimal modification. The first section will examine the structure of the network, its command and control, information flow, and other considerations. The following section will examine the selection of interceptors, including their location and coverage areas. The third section will use the information developed in the first two, and outline the entire system, including a timeline chart.

5.2 Structure of an ABM Network

The examination of the existing missile warning network in Chapter II detailed the sensor network and the reporting chain for missile events. Several key characteristics of the network will have to be modified to integrate the ABM portion of the network, and they are addressed in the following paragraphs.

5.2.1 Command and Control. An issue of primary importance would be the control of the network. In the current missile warning network, US Space Command or NORAD control the sensor operations. The reporting chain goes from NORAD up to the National Military Command Center, to the National Command Authorities.

In a network where weapons are launched, other major Commands, and the other services may wish to enter the control network. As pointed out in Chapter II, most of the current development of interceptors is being done through the Army. Since US Space Command is a unified command with components from all services, it could technically be given operational control of the entire network. While other agencies may wish to be involved in the network, it would increase the size and complexity of the organization. Since an objective of the investigation is to integrate the ABM capabilities with minimum modifications to the existing network, it will proceed under the assumption that the entire network falls under the unified command. If the ABM launch sites were tied to the network, the organization size could be kept to a minimum, with the sites operated by an Army detachment, but responsible to the unified command, just as the radar sensors operate under the current network.

The existing network offers the communications and control facilities needed by the new ABM component. The links in the network that would have to be added are the communication systems to the launch sites, and possibly high speed data lines from the sensors or the Cheyenne Mountain Complex for tracking information.

Using the new network, a launch event would be reported in the same manner as the current system. If the event was determined to be a missile launched at the US, then the NCA would have to be contacted, and decide if an attempt to intercept the incoming missile would be made. The response could flow down the same channels it was reported on. The appropriate interceptor batteries would be brought into the communications loop, as soon as launch is detected.

The reporting chain proposed is depicted in figure 5.1 .

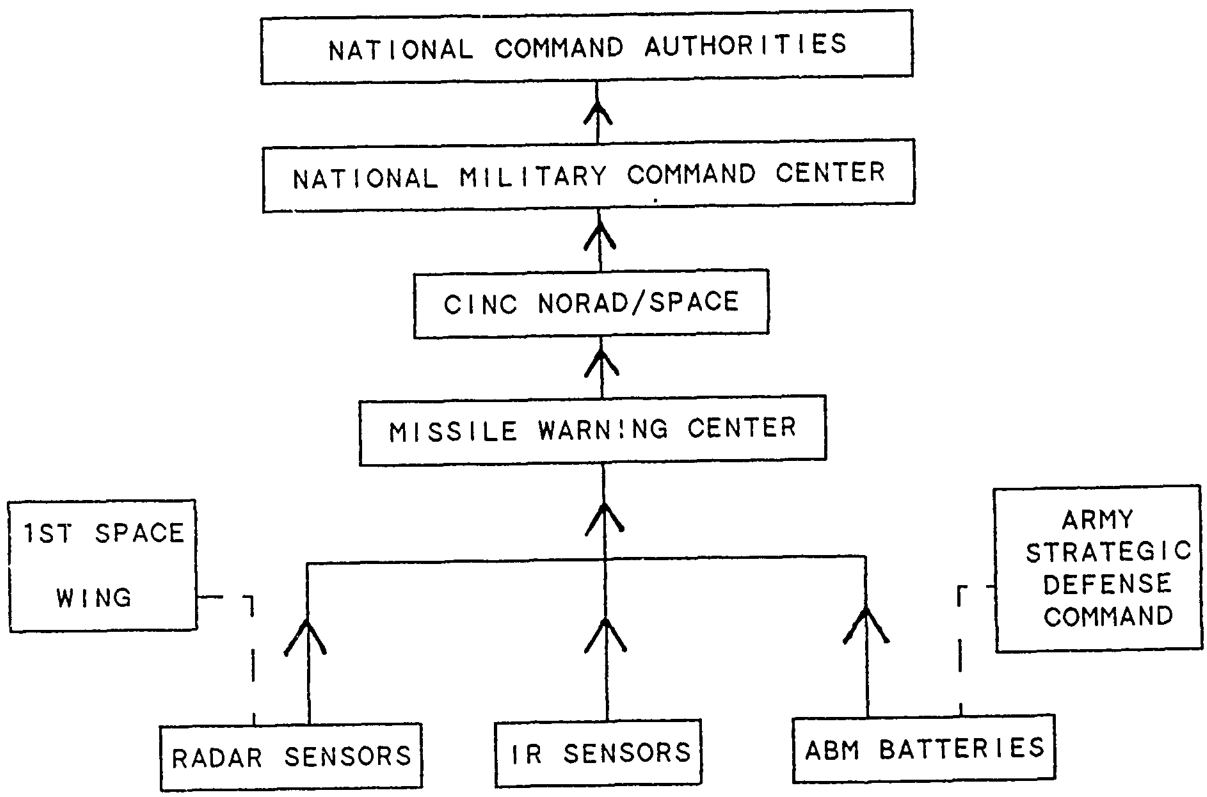


Figure 5.1. Possible System Network

5.2.2 Confirmation of the Event. Since the launch of an interceptor missile is a serious action, no one would want to launch one until it has been confirmed that there is in fact an incoming missile. A practice currently in use by the current network to determine if the event is real is the concept of Dual Phenomonology. When making an assessment of a launch, the Command Director in NORAD Cheyenne Mountain looks for the detection of an event by two separate types of sensors. For example, an launch would first be detected by a satellite, and then a radar detection of the same launch would act as confirmation of the event.

In the case of the ABM network, we will assume Dual Phenomonology has taken place as soon as radar detection occurs. While the concept may be a good indicator for assessment of an attack, it may not be considered enough confirmation to launch an interceptor. Since most of the events are detected by two or more radar sensors, another option is to wait until the second radar sensor reports the event. While this will slow the process somewhat, the communications loop could be maintained open and the NCA considering their decision while waiting for a second radar. As pointed out in Chapter III, the Comet program used in this investigation is in use in NORAD Cheyenne Mountain, and will predict when the radar sensors will report the event. If the first radar detection does not occur, it establishes a lack of Dual Phenomonolgy, and the decision must be made to launch or wait for another sensor. The results of the program shown earlier in this chapter point out the time differences between first and second radar detections.

5.2.3 Soviet Notification. The objective of this system is to counter a Third World threat, not provide an effective defense against a massive Soviet-US exchange. It may be assumed that a launch of an interceptor missile by the US will probably be detected by the Soviet Union. In order to allow installation of the system, extensive cooperation with the Soviet Union will have to take place. The Soviet Union may have to be briefed on the system: its mission, basic operations, and capabilities.

To ensure the ABM launch is not interpreted as an attack against the Soviet Union, notification of the launch to the Soviets may become necessary. The communication facilities undoubtedly exist, it should be a matter of establishing procedure. Since the National Military Command Center will be responsible for relaying the launch orders, it may be feasible for them to make notification to the Soviet authorities at the same time. Notification will prevent the element of surprise, and a single or small launch would then not present the threat of an unannounced launch.

5.3 Interceptor Determination

The results from Chapter IV can be used to help determine what type of interceptor should be used in the system. The various interceptors currently under development were reviewed to determine if one or more of them were appropriate for the system. The following sections describe the selection of an interceptor.

Several factors must be considered when determining the interceptor:

- The amount of warning time provided by the missile warning network.
- The amount of area the interceptor is to defend.
- The guidance requirements of an interceptor.
- The decision time in the network from detection to order to launch.
- The range of the interceptor; the minimum and maximum kill range.
- The desired locations of the interceptors.

With the factors listed above in mind, the following objectives were initially developed to define the needs of the proposed system:

- The entire Continental United States is to be defended.
- The interceptor will receive guidance from ground based radars, but must have an active homing device on board to locate the target.
- The interceptor should be long range, providing maximum coverage area, and minimizing the number of interceptor sites needed to provide coverage for the entire US.
- The time available for launch will vary for each launch, but will be based on radar detection time.
- The interceptors will be based in the Continental United States.

5.3.1 Time Available for Interception. The time available for interception is driven by several factors:

- Total missile flight time.

- Sensor detection time.
- Communication and processing time.
- Launch order decision time.
- Interceptor preparation time.
- Interceptor flight time.

The total time available for interception is the total missile flight time, less a combination of the remaining items, some of which can be accomplished simultaneously.

The processing of missile events currently follows a standardized, rigid procedure, with timeliness of primary importance. Decision times are reduced by anticipating upcoming events. For example, when an IR sensor detects a missile launch, the COMET program predicts when radar detection will occur. Personnel in the Missile Warning Center, the NORAD Command Post, and the National Military Command Center can anticipate their actions should the detection occur as predicted. If voice and data circuits were established with the interceptor batteries, preparation time for the interceptor batteries could be reduced by beginning the actions as soon as an IR detection occurs, and preparing for the radar detection.

The available interception time is primarily dependent on the radar interception time. Several important conclusions can be drawn from the data presented in Chapter IV:

- Launches from the Middle East region will be detected at least 800 seconds before impact.
- Launches from Cuba will be detected at least 450 seconds before impact.
- Launches from the remainder of the Latin American region will be detected at least 550 seconds before impact.

If an interceptor with a slant range of 350 to 450 miles is used, the flight time will be approximately 170 to 300 seconds (Based on a booster burnout velocity of 6-7 Km/Sec). Based on the conclusions stated above, it appears there is ample time for detection, communication of the event up chain of command, a launch decision, and interception of an incoming missile. Launches from Cuba would provide the closest time lines, but are still within the capabilities of the system. The time for communication of the event and reaching a decision would be from 170 to 270 seconds, depending on processing time and exact range. The decision time would increase with increases in range.

The above conclusion is based on the assumption the network begins the decision process as soon as a launch is detected. Having already been alerted of the launch by IR sensors, the communication of the event should be processed within two to four minutes from radar detection.

The launch decision time would become a variable based on the time until interceptor launch. Decision authorities would be advised of the time available until the interceptor should be launched, which would be based on the optimum interception range.

5.3.2 Interceptor Location. The location of interceptors is determined by the size of the area to be defended, and the range of the interceptor. The objective of the system is to use the minimum number of interceptor batteries to defend the entire continental US. The following information must be considered when determining the interceptor:

- Radar guidance will not necessarily be provided to the interceptor by the closest radar. For example, a launch from the Middle East to Beale AFB may be intercepted by a battery near Beale, but the interceptor won't receive guidance from Beale's western facing coverage.

- Given their current range capabilities, interceptors located around the periphery of the US could not defend the central US. For example, a launch from the Middle East to Kansas City would pass above the range of any interceptor based along the Eastern coast (reference figure 5.2).
- Several hundred interceptor batteries would be required to defend the entire US using interceptors with a range of 100 miles or less, such as ERINT and HEDI.
- Twelve batteries could defend the entire US using interceptors with a range of 350 miles.

Using the information above, it was determined the only practical interceptor would be ERIS. Other current interceptors have such limited range that the number of batteries needed to defend the US would seem to make them impractical. The ERIS is still in the developmental stage, and the range has not been firmly established, but the interceptor does use the Aries booster, which appears to have more than ample range (19:132). As stated in Chapter I, this investigation will not be examining the technical aspects of interception. The investigation will proceed on the assumption the ERIS will have the capability, and the issue of development is addressed in section 6.1.4.

Figure 5.3 depicts how 12 interceptor batteries with a range of 350 miles could defend the entire US. The locations of the interceptor batteries could vary, the figure shows only one possible combination. The exact locations of the batteries are flexible, as long as the entire area is covered. Possible locations could be developed by strategists who want overlap in certain areas, or based on location availability. It is important to note that the number of interceptor batteries required is entirely dependent on the range of the interceptor. If the range of the ERIS is increased, the number of batteries needed may go down. A 50 mile reduction in range (Making the range 300 miles), causes the number of batteries required to be 15. The number of interceptors at each battery would be determined by the assessment of the threat.

Initial radar guidance for the interceptors could be provided from the missile warning network through high speed data circuits. Since all sensors report their data to Cheyenne Mountain Complex, it could be rerouted to the batteries. The initial guidance would be used by the batteries to provide search coordinates for the radar that will be part of each battery.

While the system is designed to counter a small threat, additional interceptors may be desired for follow on actions. If the initial launch is unsuccessful, the battery may be able to launch another. It may or may not be assumed that once the battery receives the order to launch they would be allowed to launch a second interceptor if the first failed without additional orders.

OVERFLIGHT OF A COASTAL BASED INTERCEPTOR

LAUNCH TO A LOCATION 1600 MILES INLAND

APPROXIMATION BASED ON 32° REENTRY ANGLE

INTERCEPTOR SLANT RANGE OF 500 MILES

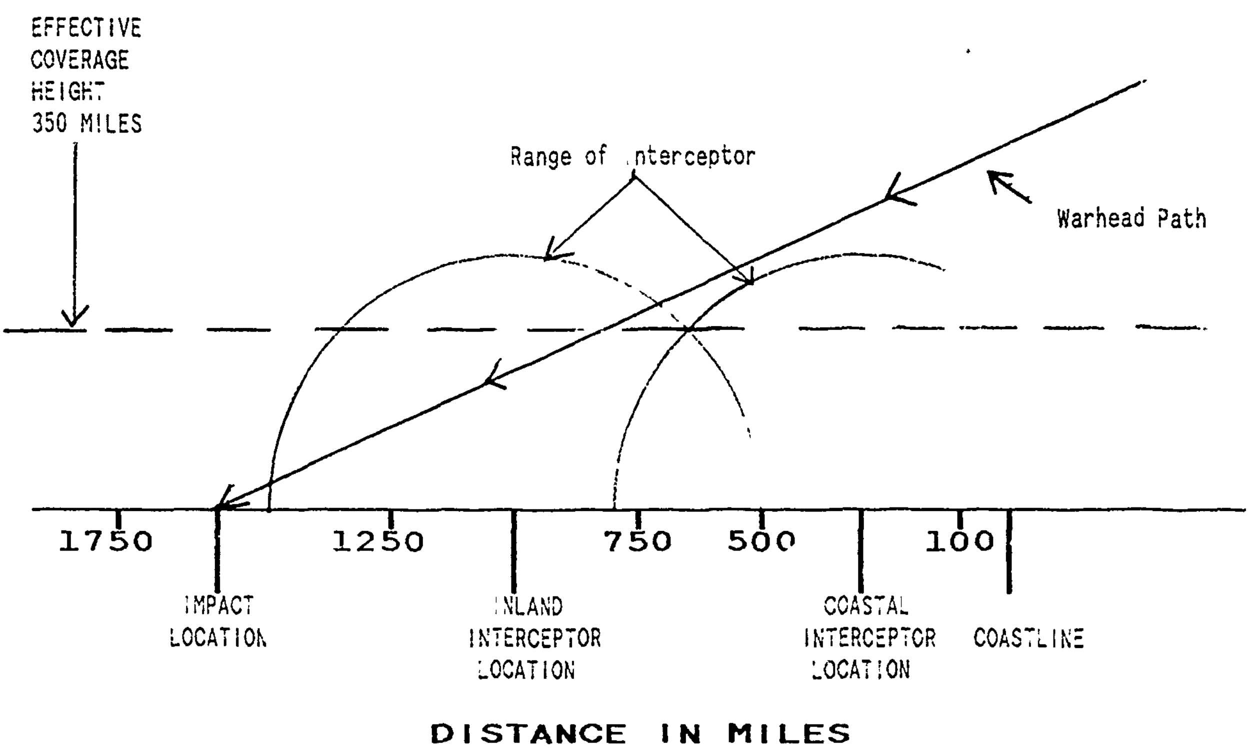


Figure 5.2. Overflight of a Coastal Based Interceptor

5.4 Network Timeline

Based on the information presented above, an ABM system consisting of twelve interceptor batteries could be tied into the existing missile warning network's chain of command and control. The information flow has been expressed in a chart in figure 5.4.

The launch and impact times in the chart are approximations, based on a sample launch from the Middle East to central US. Some of the times for communication of events through the chain of command are classified, and therefore are not listed. It should be noted that the chart is only an approximation. For this particular launch, a second radar detection time has been included. For launches from the Latin American region, the National Command Authorities may not have the time to wait for a second sensor detection. If a launch from Latin America did occur the NCA would be informed of the decision time, which would be reduced accordingly.

The actual times will vary, based on the specific launch and impact point, the interceptor range and notification times. While the times are not exact, the process should follow the same flow for all events.

It is important to note the length of time from initial NCA notification to decision time. This is the primary variable in the process, and is dependent on the missile flight time.

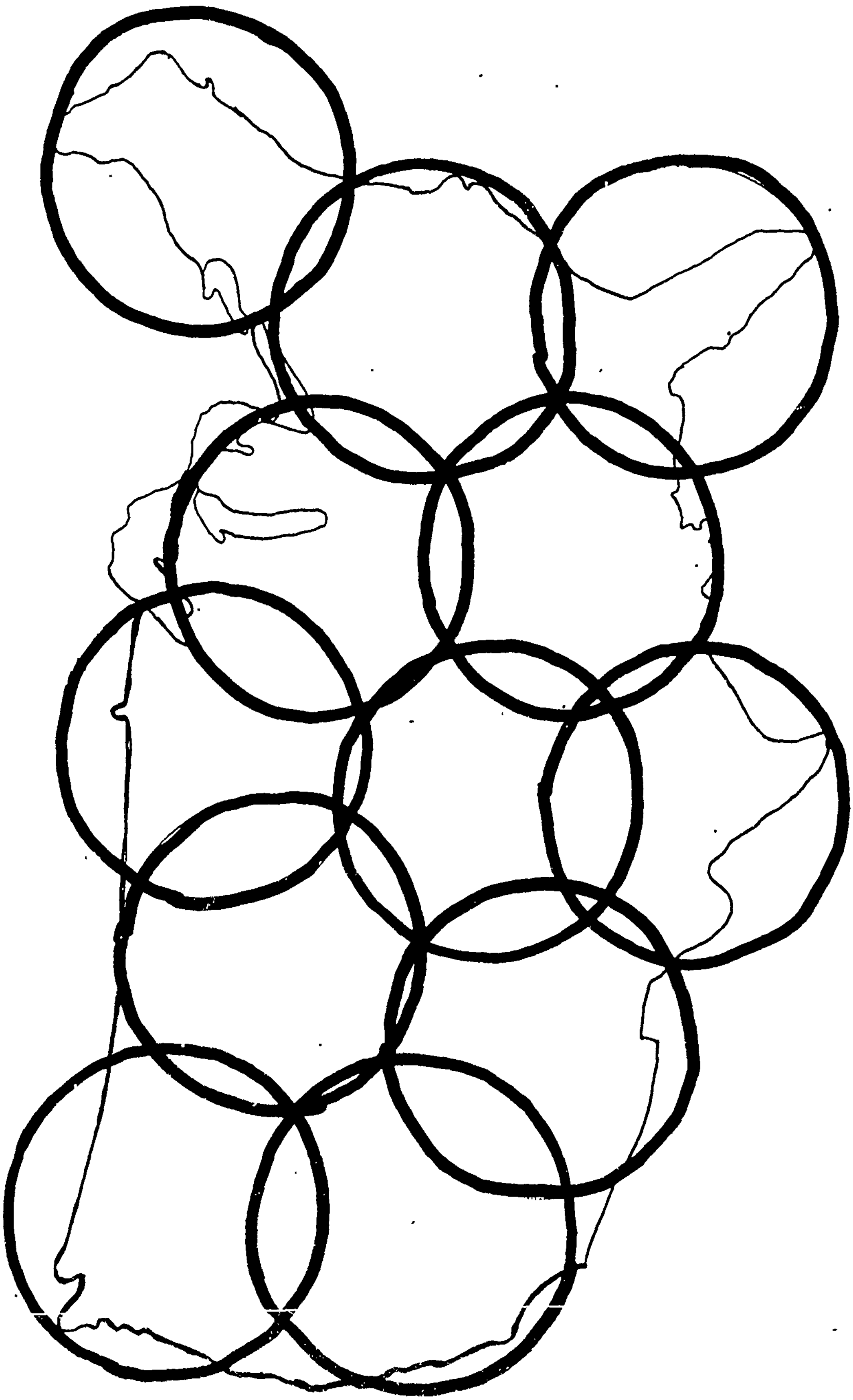
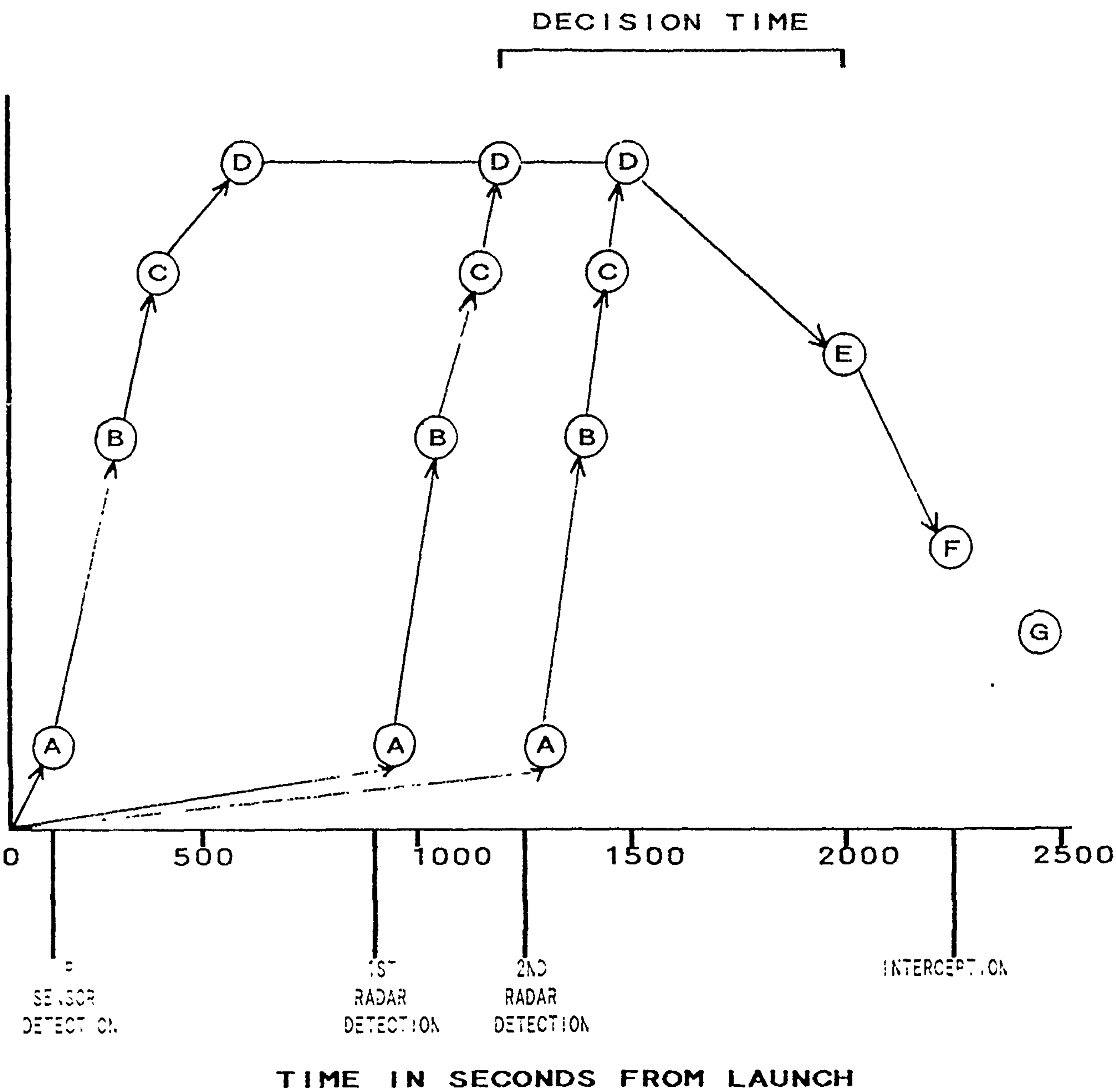


Figure 5.3. Defense of the US Using 12 Batteries



SAMPLE LAUNCH FROM MIDDLE EAST TO CENTRAL US

Times Shown Are Approximate

A = SENSOR DETECTION
B = SENSOR NOTIFIES MWC
C = MWC NOTIFIES NMCC
D = NMCC NOTIFIES NCA

E = INTERCEPTOR LAUNCH
F = INTERCEPTION
G = PREDICTED IMPACT TIME

Figure 5.4. Timeline diagram for Network

VI. Conclusions and Recommendations

6.1 Overall Conclusions

Some very general conclusions can be drawn from this investigation. They are listed below, and will be discussed in more detail in the following sections.

- The existing missile warning network is capable of detecting launches from Third World locations to the United States.
- The warning times provided by the network are adequate to allow for the preparation and launch of an interceptor, which would intercept the incoming missile in the late mid-course or early terminal phases of flight.
- An ABM system could be integrated into the existing warning network's command and control structure with minimal modifications.
- The proposed system is based on the use of the ERIS interceptor, which is still in the developmental stage, and represents the biggest uncertainty in the system.

6.1.1 Missile Warning Network. It appears the existing missile warning network will detect launches from Third World regions. The computer model used simulated 11,900 launches, and all but 326 were detected. All of the 326 not detected appear to have been caused by the missile type used in the model rather than the failure of the network to detect them. While the launch points used can not represent every possible launch location, they do represent a credible portion of the threat area. Considering the effort that went into the design and development of the network, it is not suprising to find it so effective.

6.1.2 Warning Times. The warning times provided by the existing missile warning network appear to be adequate to support an ABM system. If a launch was detected late in flight, there would be insufficient time to communicate the warning, establish its authenticity, and decide to launch an interceptor before the missile impacted. The network does provide enough warning time of launches to avoid this scenario. The network warned of launches from Middle Eastern areas at least 800 seconds before impact. Launches from northern Latin American areas (Cuba) result in the least warning time, as little as 450 seconds. Even the shortest flights appear to provide adequate time for interception. Warning time can be the most important variable in a interception problem, but appears not to be a problem in the specific case of launches against the US.

6.1.3 Network Modifications. An ABM system could be integrated into the control structure of the existing warning network with minimal modifications. The current warning structure is controlled by a unified command. ABM batteries could become part of the command by simply adding communication links. As proposed, the system would require 12 batteries to provide coverage for the entire continental US. These batteries would receive notification of launch events, initial radar guidance, and launch orders through the existing structure. While the batteries would be getting guidance from the network, it is not practical to co-locate the batteries with the radar sensors. The batteries would require computers to process the data from the network, and it would provide coordinates for the batteries' short range radar.

6.1.4 Interceptors. It appears the proposed interceptor is the most questionable link in the system. The ERIS interceptor appears to be a logical choice from among the current interceptors. The ERIS is being developed for the Strategic Defense Initiative Organization, and the complete system has not yet been tested. The range of an interceptor directly determines the amount of area it can cover. If the range of the interceptor falls below 300 miles, the number of batteries required to cover the US begins to grow rapidly, and make the system less practical.

6.2 Recommendations for Further Research

Several areas in the investigation warrant further research. Since the most questionable link in the proposed system is the interceptor, it warrants further investigation. A statistical analysis of intercept probabilities may lend insight into interceptor location and overlap of coverage. Expanding the scope of the proposed system to provide coverage for other geographic regions could be examined to determine if the existing system could provide adequate warning for other regions.

6.2.1 Interceptor Use. The ERIS interceptor is still in the developmental stage, and may or may not prove adequate for the proposed sytem. Research into current developments on a classified level may provide insight on its practicality. Research on the guidance system may determine if additional components, such as spaced based long range infrared guidance, are needed. Since the number of batteries required to defend the US is driven by the range of the interceptor, establishing the range of ERIS, and other interceptors, is important.

6.2.2 Intercept Probabilities. The proposed system assumes the interceptors will have an acceptable probability of interception. The probability of success is driven by many factors, including the probability of missile failure or guidance failure. Overlap in coverage may increase the probability of interception. An analysis of failure rates, and probability of intercept could determine the number of interceptors needed at each battery, as well as the overlap desired.

6.2.3 Expanding the System. The scope of this investigation was limited to defense of the continental US. Defense of other areas, particularly Canada, may be possible using the existing warning network. Further research may establish the value of integrating the system into the defense of NATO or other European countries.

Appendix A. *FORTRAN Source Code*

The FORTRAN code used to screen the COMET model output is shown below.

```
*****************************************************************************
*      THIS PROGRAM READS OUTPUT FROM DOMA AND SCREENS IT FOR RECORDS
*      WITH USEFUL DATA.  RECORDS WITH A RADAR INTERCEPT ARE PRINTED
*****************************************************************************
*
********************     VARIABLE DECLARATIONS     ****************************
*
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*5 IPL
*
********************     FILE OPENINGS     ***********************************
*
*       OPEN THE FILES ...THIS LINE WILL BE CHANGED FOR EACH OF THE FILES
*       INPUT = AFIT1.OUT,AFIT2.OUT, AFIT3.OUT   OUTPUT = AFIT1.RUN etc
*
      OPEN (UNIT=12, FILE='AFIT1.OUT', STATUS='OLD')
      OPEN (UNIT=13, FILE='AFIT1.RUN', STATUS='UNKNOWN')
*
*****************************************************************************
*
*    THIS READ STATEMENT READS THE OUTPUT DATA IN THE FORMAT SPECIFIED BY THE
*    NUMBER 3 STATMENT.  tHE SAME FORMAT WAS USED TO WRITE THE ORIGINAL OUTPUT
*
10    READ (12,3,END=99999)IPL,IPI,FLATL,FLONL,FLATI,FLONI,SMAXIS,ECCORB,
     & APOHT,MISSTYPE,RTIM,RAZRPT,RELRPT,RRNG,RECCT,SECTIR,SSNSPTR,IAR,PTIM,
     & PAZRPT,PELRPT,PRNG,PECCT,SECTIP,TIMPCT,IAT,STIM,SAZRPT,SELRPT,SRNG,
     & SRNG,SECCT,SECTIS,IACAP,IAS,RASTR,RECCTR,RASTS,RECCTS,TAZMUTH,
     & RAZMUTH,IACOVTIMBP,PGAMEF,PGAMI,RVGCLAT,RVGCLON,RRV,RVAZI,RVV,PVELE,
     & PVELI,SAVEDOP,SAVEDIP,AZRATE,ELRATE
*
3     FORMAT(1H ,5X,1H1,A5,I4,2X,4(F8.3,2X),F8.5,2X,F8.5,1X,F8.2,
     & I6/1H ,5X,1H2,8H  ENTER ,F6.0,2X,F8.3,3X,F7.3,2X,F8.3,2X,
     & F8.3,2X,F6.0,4X,F5.0,2X,A1/1H ,5X,1H3,8H REPORT ,F6.0,2X,
     & F8.3,3X,F7.3,2(2X,F8.3),2X,F6.0,3X,F6.0,2X,A1/1H ,5X,1H4,
     & 8H  EXIT  ,F6.0,4(2X,F8.3),2X,F6.0,4X,A4,3X,A1/
     & 1H ,5X,1H5,8H  R&S   ,F6.0,2X,F8.3,4X,F6.0,3(2X,F8.3),2X,A4/
     & 1H ,5X,1H6,8H BURNOUT,F6.0,2X,F8.3,2X,F8.3,5(2X,F8.3)/
     & 1H ,5X,1H7,8X,2F8.2,2F10.2,2F10.4/)
*
*
*           THIS BLOCK DETERMINES IF THE DATA HAS A SENSOR INTERCEPT
*           ON THE OUTPUT RECORD, BY CHECKING THE ENTRY TIME.  IF THE
*           TIME HAS A ZERO VALUE, THE EIGHT LINE RECORD IS DISCARDED.
*           IF THE RECORD DOES HAVE AN INTERCEPT, THE FIRST TWO LINES
*           OF THE RECORD ARE WRITTEN BY THE #4 FORMAT STATEMENT.
*
      IF (RTIM .EQ. 0.000) THEN
      GO TO 10
      ELSE
      WRITE (13,4) IPL,IPI,FLATL,FLONL,FLATI,FLONI,SMAXIS,ECCORB,
     & APOHT,MISSTYPE,RTIM,RAZRPT,RELRPT,RRNG,RECCT,SECTIR,
     & SNSPTR,TIMPCT
      END IF
*
4     FORMAT(1H ,5X,1H1,A5,I4,2X,4(F8.3,2X),F8.5,2X,F8.5,1X,
     & F8.2,I6/1H ,5X,1H2,8H  ENTER ,F6.0,2X,F8.3,3X,F7.3,
     & 2X,F8.3,2X,F8.3,2X,F6.0,4X,F5.0,2X,A1,2X,F6.0/)
*
*     THIS "GO TO" RETURNS THE PROGRAM TO READ ANOTHER RECORD
*
      GO TO 10
*
99999 CLOSE (UNIT = 12, STATUS ='KEEP')
      ENDFILE 13
      END
```

Appendix B. *Missile Range Computation*

B.1 Analysis of Undetected Launches

Initial analysis of the computer output of the Middle East launch region revealed 203 of the 7350 launches were not detected by the radar network. Further examination revealed all of the launches were from southern areas of the launch region (from 5 to 20 degrees North Latitude), to southern areas of the impact region (below 34 degrees North Latitude). It appears these launches have among the longest flight ranges of all the launches from this area. This led to the hypothesis that the problem could possibly be in the computer model, rather than launches that could not be detected. If the model used a missile type with a range less than the flight distances for these launches, the results would show no detection.

Since virtually all the undetected launches appeared to be long range, some computations were done to determine the approximate range of their flight. Ten launch and impact points were selected as typical of those that were undetected, and then examined. The formulas used to compute the range were either taken directly or derived from those provided in *Fundamentals of Astrodynamics.*

First, the geodetic latitude of the points were converted to geocentric coordinates, using the following equations:

$$C = \frac{1}{(\cos^2\phi + (1-f)^2 \cdot \sin^2\phi)^{\frac{1}{2}}} \tag{B.1}$$

$$f = \left(1 - \frac{E_p}{E_e}\right) \tag{B.2}$$

$$S = (1-f)^2 \times C \tag{B.3}$$

$$R = \left(\frac{1}{2} \cdot (S^2 + C^2_{+}\frac{1}{2}(C^2 = S^2)\cos(2\cdot\phi)\right)^{\frac{1}{2}} \tag{B.4}$$

$$\tag{B.5}$$

where

ϕ = geodetic Latitude

f = flattening factor to account for earth's oblateness

E_p = Radius of the earth at the poles, 6378.145 km

E_e = Radius of the earth at the equator, 6356.785 km

Solving the above equations allows the determination of geocentric latitude ϕ' through the following equation:

$$\pi' = \arctan\left((1-f)^2 \cdot \tan(\pi)\right) \tag{B.6}$$

Once the geocentric coordinates are determined, the angle between the two points on the earth's surface, with the apex of the angle at the center of the earth, is determined with the following equation:

$$\Phi = \arccos(\cos\phi'_L \cdot \cos\phi'_I \cdot \cos(\lambda_I - \lambda_L) + \sin\phi'_L \cdot \sin\phi'_I) \qquad \text{(B.7)}$$

where

ϕ'_L is geocentric latitude of Launch Point

ϕ'_I is geocentric latitude of Impact Point

λ_I is longitude of Impact Point

λ_L is longitude of Launch Point

The ground distance between the two points can then be determined as a measure of arc, by assuming the earth is spherical, and using the following equation:

$$\text{Range} = \Phi \cdot r \qquad \text{(B.8)}$$

where

r is the radius to surface.

Since this radius will vary, an approximate average value of 6378 km was used.

The ground range solved for using the method described above does not take into account the earth's rotation. The additional energy required to overcome the earth's momentum and direct a missile in a westerly direction is usually greater than the additional time gained by the earth's rotation. There are sevral factors that affect the range of a launch:

- The azimuth of the launch.
- The effect of the earth's rotation as contributing to the inertial range capability of an easterly launched, and reducing the inertial range capability of a westerly launched, missile.
- The effect of the earth's rotation as reducing the distance between launch and impact points for easterly launches, and increasing the range for westerly launches.
- The rotational effects on the inertial range of the missile usually outweigh those on the reduced distance, resulting in most missiles having a longer flight range for a easterly launch than a westerly launch.

Assuming the range of a westerly flight could possibly be reduced by the rotation of the earth, a calculation of rotation during flight was completed. The maximum ground distance reduction would be at the equator, and would gradually reduce with an increase in latitude. The velocity of the earth with respect to a ground point can be represented by the following equation:

$$V_0 = 1524 \cos L_0 (ft/sec) \tag{B.9}$$

where

V_0 is the velocity at the launch point on the surface of the earth.

L_0 is the latitude of the launch point.

The range for each of the ten launch and impact points were determined using the above equations. The range was then reduced by a computation of the earth's rotation during flight time. The latitude of the launch location was used in each case, with a flight time of 2600 seconds. The flight time was an approximation based on the output from the model. The maximum flight time found in any of the launches from area one was 2600 seconds. This will result in a figure that is no doubt generous for the actual distance the earth would rotate, since the launches will be going over the pole and not directly eastward, but if the range is excessive using this calculation, it will undoubtedly be excessive with a smaller amount of earth rotation. The data from the launch and impact locations was entered into MATHCAD, and the results are shown in table B.1.

As described in Chapter III, the model requires a missile type to determine the trajectory. The missile types maintained for the model are standard Soviet missiles. When requesting the use of the model for this investigation, we requested any missile type using a minimum energy trajectory. Since all of the ranges determined above appear to be beyond the standard range of Soviet SS-11, SS-13, or SS-18 missiles, it was determined the missile type used in the model did not have sufficient range for these particular launches. The problem with the undetected launches appears to be from the use of a missile type with insufficient range, not with a lack of radar coverage.

LAUNCH LOCATION N/E	IMPACT LOCATION N/E	GROUND RANGE MILES	ROTATIONAL DISTANCE	NET DISTANCE MILES
5/65	42/273	8765	747	8018
5/80	38/278	9273	747	8526
10/30	34/250	8443	739	7704
10/55	34/264	8874	739	8135
10/65	30/257	9586	739	8847
15/45	30/257	8692	724	7968
15/65	28/279	9718	724	7994
15/90	31/278	9243	724	8518
20/65	30/268	8686	705	7981
20/85	28/279	9020	705	8135

Table B.1. Range Between Launch and Impact Locations

Bibliography

1. Albright, David "Pakistan's Making Capacity," *Bulletin of the Atomic Scientists*, 43:30-32 (June 1987).

2. Barnaby, Frank, "The Nuclear Arsenal in the Middle East," *Technology Review*, 90:27-34 (May - June 1987).

3. Barnaby, C. F. and A. Boserup. *Implications of Anti- Ballistic Missile Systems.* New York: The Humanities Press, 1969.

4. Barnby, Major Lee M., Surveilance Officer, personal interview. J6 Staff, Pentagon, September 6, 1990.

5. Carter, Ashton B. and David N. Schwartz. *Ballistic Missile Defense.* Washington, D.C.: The Brookings Institution, 1984

6. Chayes, Abram and Jerome B. Weisner. *ABM An Evaluation of the Decision to Deploy an Antiballistic Missile System.* New York: Harper and Row, 1969.

7. Department of the Air Force, 1013 Combat Crew Training Squadron. *Space Operations Orientation Course.* Peterson AFB, 1989.

8. Department of the Air Force, 1013 Combat Crew Training Squadron. *USAF Training Program, Introduction to BMEWS.* Peterson AFB, 1982

9. Du Sablon, Jean LeClerc, "Trying to join the club of great nations: an unexpected change in the world caste system." *World Press Review :24-25.*(June 1988).

10. Holst. Johan J. and William Schneider. *Why ABM? Policy Issues in the Missile Defense Controversy.* New York: Pergamon Press, 1969.

11. "How quickly can Irag get the Bomb?" *U.S. News and World Report*, 108:49-50 (June 4, 1990).

12. James, Steve, Analyst, personal interview. Directorate of Missile Warning, Air Force Space Command, Peterson AFB, CO, June 23, 1990.

13. Matthews, William, "SDI Backers See Third World Missile Threat," *Air Force Times*, (April 9, 1990).

14. Morse, Major Ronald L., Division Chief, Missile Warning Training Division, Telephone interview. 1013 Combat Crew Training Squadron, Peterson AFB, CO, October 10, 1990.

15. Nordland, Rod, "A Pakistan Bombshell, New Evidence it has Nuclear Arms," *Newsweek 15:109*(March 16, 1987).

16. Quester, George H., "Nuclear Proliferation in Latin America," *Current History*, 81:52-56 (February 1982).

17. "Rail-Launched HEDI Vehicle Makes First Flight; Test Terminated by Premature Warhead Separation," *Aviation Week and Space Technology*, 132:33 (February 5, 1990).

18. Rhea, John, "With Changing Times, Army Shifts SDI Focus." *Washington Technology*, 7-9 (March 22 - April 4, 1990).

19. Schomisch. J. W. 1989. *Guide to the Strategic Defense Initiative.* Arlington, Virginia: Pasha Publications, 1989.

20. U.S. Congress, Office of Technology Assessment. *Ballistic Missile Defense Technologies, OTA-ISC-254.* Washington, D.C.: U.S. Government Printing Office, 1985.

21. US Executive Office. *Treaty Between the United States of America and the Union of Soviet Socialist Republics of the Limitation of Anti-Ballistic Missile Systems.* Signed May 26, 1972. Washington, D.C.: Government Printing Office, 1972.

22. Yanarella, Ernest J. *The Missile Defense Controversy.* Lexington: The University Press of Kentucky, 1977.

23. "Youngest Bomb Father," *Bulletion of the Atomic Scientists*, 45:5 (November 1989).

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
November 1990

3. REPORT TYPE AND DATES COVERED
Master's Thesis

4. TITLE AND SUBTITLE
A LIMITED ANTIBALLISTIC MISSILE SYSTEM

5. FUNDING NUMBERS

6. AUTHOR(S)
Jay H. Payne, Capt, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology, WPAFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GSO/ENS/90D-14

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*) This investigation examines the possibilities of deploying a limited ABM system to counter launches from Third World Nations. It is a systems analysis of the entire concept, with the objective of determining if the existing missile warning network could detect launches from Third World regions, and if an ABM component could be integrated into the network. A computer model was used to determine if launches would be detected, and examine the warning time provided. Based on sample data, the warning network appears capable of detecting Third World launches. Warning times provided by the network appear to provide adequate time to communicate the event up through the National Command Authorities, and launch an interceptor. The ABM structure could be integrated into the existing network, using the unified command currently operating it. The entire US could be defended using 12 batteries of interceptors with a range of 350 miles. It appears the most questionable aspect of the entire concept is the interceptor missiles. There are several interceptors currently under development, but none have been fully operationally tested. The ERIS interceptor under development by the Army may have the needed capability to be used in the system. Further research could prove the system invaluable.

14. SUBJECT TERMS
Antiballistic Missiles, Missile Warning System, Ballistic Missiles

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	